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A HEAVY METAL STUDY OF THREE RIVER BASINS IN ATLANTIC CANADA INFLUENCED BY MINING ACTIVITIES

IW/L-AR-WQB-88-138

Canada

INLAND WATERS DIRECTORATE
ATLANTIC REGION
WATER QUALITY BRANCH
MONCTON, NEW BRUNSWICK

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ABSTRACT

Water, sediment and fish samples were collected from three river basins in the Atlantic Region which have been influenced by base metal mining activities. Three of thirty-six water sampling sites had heavy metal levels exceeding water quality guidelines for the protection of aquatic life. They included two sites on the Tomogonops River (Northwest Miramichi River Basin) in New Brunswick and Buchans Brook (Exploits River Basin) in Newfoundland. Heavy metals in bottom sediments ranged from enriched or slightly above background levels (Mira River) to excessive (Red Indian Lake). The range of values for Red Indian Lake sites were arsenic - 100 to 260 mg/kg, cadmium - 1.4 to 10. mg/kg, lead - 1500-2600 mg/kg and mercury - 0.24-1.0 mg/kg. Forage fish in the Northwest Miramichi River bioaccumulated zinc about 4 times the normal range of concentration of zinc in fish, whereas large fish in Red Indian Lake bioaccumulated low levels of metals indicative of unpolluted areas in spite of the heavily contaminated bottom sediments.

RESUME

Des échantillons d'eau, de sédiments et de poissons ont été recueillis dans trois bassins versants situés dans la région de l'Atlantique. Dans le passé, ces trois bassins furent sous l'influence d'activités d'exploitation minière pour des métaux communs. Trois des trente-trois sites d'échantillonnage avaient des concentrations de métaux lourds dans l'eau excédant les lignes directrices recommandées pour la protection de la vie aquatique. Deux de ces sites furent localisés sur la rivière Tomogonops (nord-ouest du bassin de la rivière Miramichi) au Nouveau-Brunswick et sur le ruisseau Buchans (bassin de la rivière des Exploits) à Terre-Neuve. Dans les sédiments de fonds analysés, les niveaux de métaux lourds variaient de faibles (rivière Mira) à excessifs (lac Red Indian). Les concentrations de certains paramètres mesurés dans les échantillons recueillis au lac Red Indian sont les suivantes: de 100 à 260 mg/kg d'arsenic, de 1.4 à 10. mg/kg de cadmium, de 1500 à 2600 mg/kg de plomb et de 0.24 à 1.0 mg/kg de mercure. Les poissons de fourrage recueillis dans la rivière Miramichi du nord-ouest démontrèrent une bioaccumulation de zinc jusqu'à quatre fois supérieure aux niveaux de concentration de ce métal observé normalement dans la chair de poisson. Cependant, les poissons adultes du lac Red Indian n'ont pas démontré une bioaccumulation de métaux

aussi importante, car les concentrations de métaux mésurées dans leur chair furent celles de poissons qui vivent dans des régions non-polluées. Ceci a été observé malgré le fait que les sédiments de fond de ce lac étaient fortement contaminés de métaux.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Mining has been a major contributor to the economy of the Atlantic Region in terms of employment and revenue. For example in New Brunswick, development of known areas of mineralization during the 1960's was primarily responsible for a dramatic increase in Provincial mineral production values from $18.8 million in 1961 to $107.4 million in 1971. In 1971 metal production in the Northeastern part of the Province accounted for 85 per cent of the total Provincial mineral value which, in turn, accounted for 4.8 per cent of the gross Provincial product (Montreal Engineering Company, 1973). However in Atlantic Canada as well as other parts of North America, these mining activities have had a considerable impact on the aquatic environment (Crecelius et al., 1975, Bradley et al., 1986, Mudroch et al., 1985, Sprague et al., 1963, Morry et al., 1977, Westlake et al., 1983).

In 1984-1985, the Water Quality Branch, Inland Waters Directorate of Environment Canada (Atlantic Region) undertook a series of surveys to evaluate the environmental quality of streams whose basins have been subjected to base metal mining activities. The basins selected were the Tomogonops/ Northwest Miramichi River in New Brunswick, the Exploits River in Newfoundland and the Salmon/Mira River in Nova Scotia.

All three basins have been the subject of previous studies, (Sprague and Carson, 1966; Cowley, 1962, 1963; Chamut, 1970; Wilson, 1974; Morry and Cole, 1977; Westlake and Smith, 1983). The Northwest Miramichi and the Exploits represent some of the most productive Atlantic Salmon (Salmo salar) rivers in the Atlantic Region.

Most of the previous studies have been centered on water analyses and the present surveys update that work and determine whether there has been long-term degradation or improvement in major ion and metal levels. Metal data are also compared to water quality guidelines for the protection of aquatic life.

In addition to water, bottom sediments and fish from each basin have been analyzed. The sediment samples may determine the degree of metal contamination which has occurred while the fish may indicate the availability of these metals to the biota and whether the level of accumulation may pose a health risk to the consumer.

The surveys were conducted on the following dates:

(1) Tomogonops/Northwest Miramichi River Basin - June 1984

(2) Exploits River Basin - July 1984

(3) Salmon/Mira River Basin - September and October 1985

1.1 BASIN DESCRIPTION AND MINING ACTIVITIES

1.1.1 Northwest Miramichi River Basin

The Miramichi River Basin drains 11,700 km^2 of central New Brunswick, occupies about one-sixth of the total land area, and is the second largest basin in the province. The Northwest Miramichi, which drains 3,900 km^2, flows in an easterly and southerly direction to join the Southwest Miramichi River near Newcastle to form the Miramichi River which then flows easterly into the Gulf of St. Lawrence. There are no lakes of significant size in the well-forested basin, although there are numerous small bodies of water.

The headwaters of the Northwest Miramichi River rise in the Miramichi Highlands then flow southeasterly through the relatively low relief of the St. Lawrence Plain to the Gulf of St. Lawrence.

Most of the Northwest Miramichi River Basin falls in the northern Miramichi mineral zone which is underlain by highly deformed, regionally metamorphosed, volcanic and sedimentary rocks of the Tetagouche Group, which in part are of Ordovician age. They are intruded by Devonian granite batholiths in the southwest and stock in the northeast.

The Miramichi zone contains massive strata-bound sulphide deposits that extend over a roughly circular pattern with a diameter of about 64 kilometres in the Bathurst-Newcastle area. Total reserves in excess of 300 million tons of lead and zinc have been verified in the region.

The Heath Steele Mine property is situated 50 kilometres northwest of Newcastle in the drainage area of the Tomogonops River which is a major tributary of the Northwest Miramichi River. It is the second largest base metal mine in New Brunswick with known reserves of more than 34 million tons (Montreal Engineering Company, 1972). Twelve sulphide bodies are grouped in five zones with pyrite-sphalerite-galena as the main mineral assemblage in most ore bodies. A chalcopyrite-pyrrhotite assemblage was predominate in one ore body (McFarlane and Gates, __). Mining operations began in 1955. The mill was brought into operation in 1956 with a capacity of 1500 tons/day but low metal prices and difficulties in milling metallurgy caused the whole operation to be closed down in 1958. All the workings were flooded (Montreal Engineering Company, 1972).

In 1960, dewatering of the shafts and B - pit directly into the Little South Tomogonops River caused extremely high concentrations of heavy metals throughout the downstream Northwest Miramichi system resulting in avoidance reaction by upstream migrating Atlantic Salmon (Salmo salar), the cause

was recognized late in 1960, and treatment of drainage water was commenced (Montreal Engineering Company, 1972).

The unusual avoidance reactions of salmon at the counting fence at Curventon (10 km below Wayerton) in 1960 prompted Fisheries Research Board to begin a water sampling and analysis program. These studies resulted in the preparation of twelve Manuscript Series Reports of Chemical Conditions on the Northwest Miramichi River from 1960 to 1973.

Milling operations resumed in 1962 and capacity was increased to 3000 tons per day by 1972. Although improved effluent and drainage control works were installed, the number and diversity of sources of contamination posed problems. In 1969, an increase in pollution levels and metal toxicity led to a program of improved site drainage control which resulted in a reduction of heavy metals to less than 5 percent of the previous levels (Montreal Engineering Company, 1972).

All effluent streams discharge into a 60 hectare tailings pond which forms the sole treatment unit of the mine. Mine water and surface water drainage are pumped to a holding pond before being pumped to the tailings pond. Lime is added to the process effluent in the mill for treatment purposes and the amount is adjusted according to the volume of effluent from the holding pond (Montreal Engineering Company, 1972).

The mining operations at Heath Steele had been suspended in 1983 due to low base metal prices though some milling of silver ores was taking place.

1.1.2 Exploits River Basin

The Exploits River Basin is the largest on the Island of Newfoundland draining an area of approximately 11,000 km^2 in central Newfoundland. It has a reach of nearly 430 kilometres and empties into the Bay of Exploits near Botwood. It drains numerous headwater and chain lakes, the largest of which is Red Indian lake with a surface area of 175 km^2. Lloyds River is the largest tributary which flows into Red Indian Lake. As well, there are a number of smaller inflowing streams of which Buchans Brook is the largest.

The Exploits River, from the Exploits Dam to Norris Arm, measures about 112 kilometres. The river is well confined within banks 150 to 450 m apart and the slope is slight to moderate with a total drop of 152 metres.

The river bottom consists mainly of medium to large gravel mixed with stones and fine rubble. The centre section of the river is generally fairly shallow where depth may be less than 0.3 metres, although there are local stretches where depth may exceed 3 metres. The Exploits Estuary begins 1.5 kilometres downstream from Bishops Falls (Wilson, 1974).

The area above Exploits Dam on the upper basin lies mainly in a region of Ordovician volcanic rocks. At the northern end of Red Indian Lake there is an outcrop of underdefined Ordovician sedimentaries and a small outcrop of either Pennsylvanian or Mississippian sediments on the southwest shore.

Drainages to the west of the lake lie in a region of granites with small outcrops of diorites and gabbros. Rock in the lower drainage basin is mostly Ordovician sedimentaries downstream to Grand Falls area. To the east of Grand Falls, the basin lies over ultra basic rocks, with igneous, ultra basic and granitic bedrock to the northwest (Wilson, 1974).

The topography surrounding Red Indian lake is generally hilly and well wooded with black spruce, balsam fir and birch. One and a half to nine kilometres from the lake, the forest gives way to scattered shrubs, bogs, small lakes and basins typical of Newfoundland's Central Plateau. The banks of the main river and its tributaries are heavily wooded for most of their lengths. Forest areas in the lower basin consist largely of virgin and regenerated balsam fir and regenerated black spruce (Wilson, 1974).

Man's activities in the upper basin were very limited until a lumber operation began at Millertown on the shores of

Red Indian Lake at the turn of the century. In 1905, a dam was constructed at the outlet of Red Indian to regulate flows to float logs down the river and to generate electricity at Grand Falls. Also, in 1905, copper and zinc deposits were discovered in the area of Buchans and mining operations commenced in 1928 (Morry and Cole, 1977).

Anthropogenic activities are more prevalent in the lower basin from Badger to the Bay of Exploits with forest operations in support of the pulp mill at Grand Falls. Four population centres in this portion of the basin include Badger, Windsor, Grand Falls and Bishops Falls.

The Exploits River is one of the most productive Atlantic Salmon (Salmo salar) rivers in Newfoundland due partly to a major Atlantic Salmon enhancement program which began in 1967. By means of fishway construction on tributaries and a vigorous stocking program, the river was expected to be 40% accessible as compared to 10% in 1967. The fishway recently begun at the Exploits Dam at Red Indian Lake will open up the entire 11,000 km^2 watershed to salmon.

Prior to the implementation of the salmon enhancement program, numerous water quality studies in the Exploits River Basin were conducted, including Seabrook (1962), Cowley (1962, 1963), Chamut (1969), and Wilson (1974). Morry and Cole

(1977) prepared an in-depth limnological survey of Red Indian Lake.

The Buchans Mining Company, later taken over by American Smelting and Refining Company (ASARCO) began operation of a base metal mine and concentrator at Buchans in 1927. The 1000 ton a day mill produced approximately 9,000 tons of copper concentrate, 39,000 tons of lead, and 69,000 tons of zinc annually.

Prior to 1961, there was no treatment of the annual 200,000 plus tons of tailings coming from the Buchans mill before it was pumped into Buchans Brook. The first fully operational settling ponds came in 1966 with the use of lime as a precipitant in 1969. Though the settling ponds reduced levels of copper and zinc, a reddish-brown "fan" of tailings fines was readily visible at the mouth of Buchans Brook (Morry and Cole, 1977). This discolored area covered a distance approximately 7 kilometres by several hundred metres wide during the survey of Seabrook (1962). The extent and direction of the tailings fan area depended on prevailing winds. Core samples taken by Morry and Cole (1977) determined that critically high levels of metals were found in all surface sediments and that depth of tailings associated sediment decreased with increasing distance from Buchans Brook.

Annual ore production (Table 1 - Neary, 1986 - Personal Communication) began to decline in 1979. The mine was closed in 1982 with light to moderate production in 1983 and 1984. Operations ceased in September 1984.

TABLE 1: ANNUAL ORE PRODUCTION AT BUCHANS (1970-1984)

YEAR	ORE-TONS	YEAR	ORE-TONS
1970	359,000	1978	202,000
1971	173,000	1979	125,000
1972	291,000	1980	83,000
1973	124,000	1981	76,000
1974	264,000	1982	NIL
1975	232,000	1983	42,000
1976	208,000	1984	102,000
1977	192,000		

1.1.3 Mira River Basin

The Mira River Basin is the dominant physical feature in the eastern half of Cape Breton in the province of Nova Scotia. The river is approximately 44 kilometres in length, and drains an area of 645 square kilometres, 200 square kilometres of which are drained by the tributary Salmon River. Except for a section midway in its length, and at its mouth, the river is wide, and in general, water movement is relatively slow (Campbell, 1976).

Geologically, the area consists of gravelly loam underlain by shale and sandstone of the Cambrian period. Granite outcroppings form the material of higher elevations (Campbell, 1976). A well defined lead domain is centered in the Salmon River Basin with copper, zinc, antimony, boron, and silver deposits extending throughout the Mira River Basin (Chatterjee, 1983). Soils of the Thom, Shubie, Kirkhill, Torbrook and Springhill Series are predominate in the watershed area. Soils in all series are noted for being very acid and pH's of the upper horizons generally fall in the range from 3.5 to 4.5 pH units (Campbell, 1976).

The drainage basin terrain is classifiable as "nearly level" to "strongly rolling" with slopes ranging from 3 to 15 percent. Elevations reach 600 feet in the western portion of the watershed.

The area is forested, with the exception of a small amount of cleared land. Forest cover is mainly spruce, balsam fir, maples and birches. In the northern region, tracts of scrubland are common and the cover is chiefly Labrador Tea and similar vegetation (Campbell, 1976).

Except for the area along the river's banks, the Mira River drainage basin is uninhabited and virtually unaffected by man's activities.

In 1979, Java Mines Limited began operating a 600 ton per day lead mine on the Salmon River near Silver Springs, 20 kilometres above the confluence on the Mira River. The ore body consisted of disseminated galena in a matrix of calcareous sandstone and limestone pebble conglomerate. Pyrite was present in only trace quantities (less than 3%) (Montreal Engineering Ltd., 1979). The mined ore ranged from 4 to 4.7% lead and the life of the mine was 5 to 10 years based on total reserves. The mine ceased operation in late 1981.

Mine drainage in the order 2600 to 5200 m^3/day at a concentration of 50 to 60 mg/L lead was allowed to settle in a series of ponds before being discharged to the Salmon River. Further treatment was unnecessary since the mine was not acid producing. As mine production increased, the treatment ponds became inadequate for effluent flows and provided for lessened settling times.

As a result, grab samples collected by Yava Mines and N.S. DOE frequently had lead and suspended solids levels which exceeded permissible levels regulated by the Canada Fisheries Act covering base metal mining operations. In July 1981, Environmental Protection Service of Environment Canada

undertook a survey to evaluate the impact of this activity on the receiving water (Salmon River), sediment and biota in the vicinity of the mining operation (Westlake and Smith, 1983).

2. Methodology

2.1 Sampling Program

The present two year study comprised thirty-six stations located in the Tomogonops/Northwest Miramichi, Exploits and Salmon/Mira River Basins.

Four sampling stations on the Tomogonops/N.W. Miramichi River Basin were established at stations which had been studied by Fisheries Research Board (presently Fisheries & Oceans) during their intensive surveys of the Northwest Miramichi River from 1960-1973.

In the Exploits River Basin the fourteen sampling stations were distributed as follows: six stations in Red Indian Lake from Buchans Island to Millertown, six river stations including Buchans Brook and five on Exploits River from Millertown to Bishops Falls. Two stations were located in the estuary in the Bay of Exploits.

The eighteen stations sampled in the Salmon/Mira River Basin were almost equally divided between the two rivers. The Salmon River stations extend from above what was the effluent stream of Java Mines to a previously established station 20 km downstream at Salmon River Road. The Mira River stations

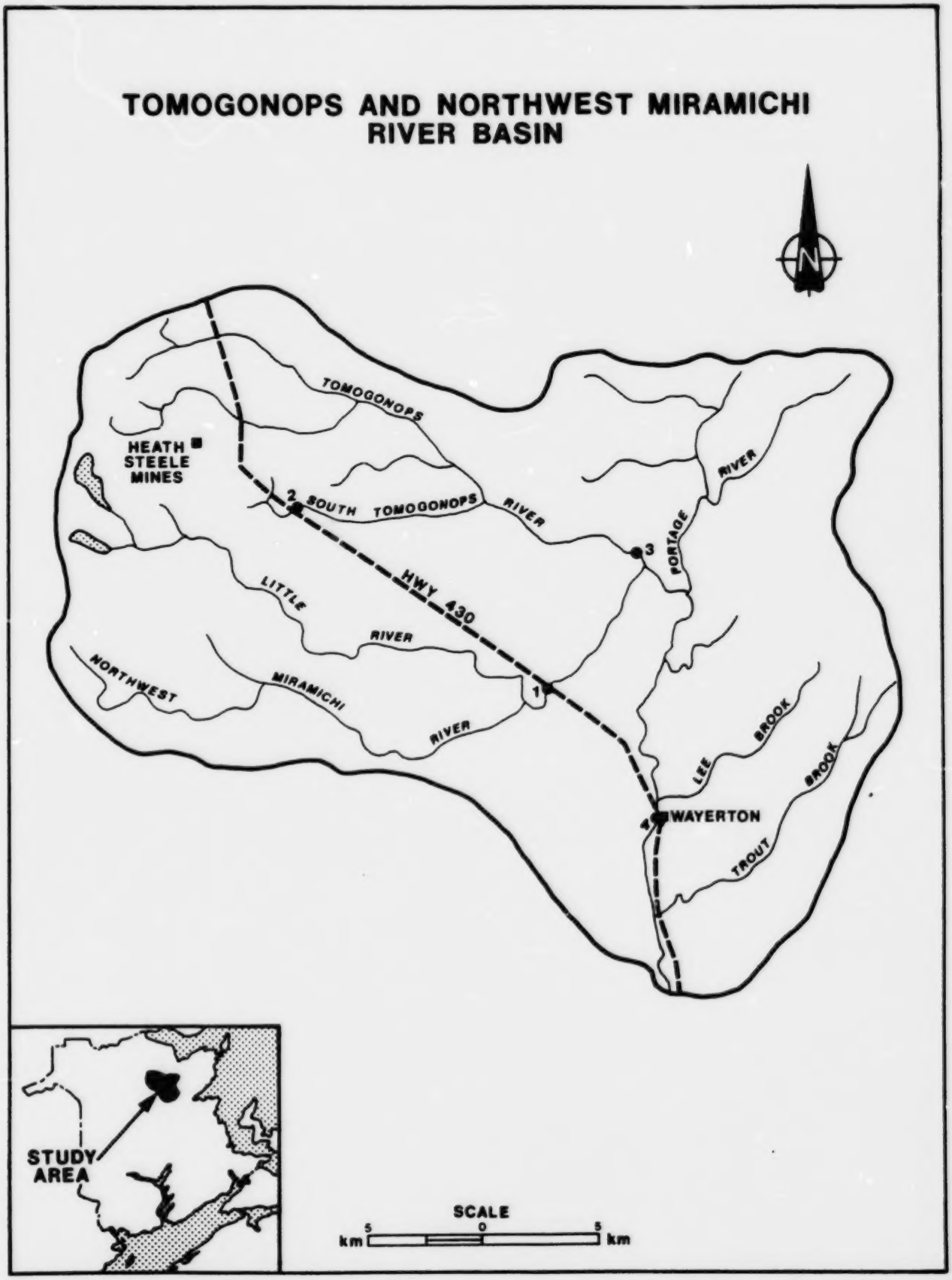
extend from 4.5 km above the confluence of the Salmon River to Mira River Provincial Park some 30 kilometres downstream.

Station descriptions and National Water Quality Data Bank (NAQUADAT) station numbers are provided in Appendix I and stations are plotted on basin maps in Figures 1 to 3.

Water and bottom sediment samples were collected at most stations with large fish or forage fish samples being collected at one site in each basin.

2.2 Parameters

Major ion, nutrients and metals were analyzed in water samples; heavy metals, total organic carbon and particle size were analyzed in bottom sediments; and heavy metals and lipid content were measured in fish tissue. A listing of all metal parameters analyzed in water, and metals and associated parameters in sediment and fish with corresponding NAQUADAT parameter codes (Water Quality Branch, 1986) and detection limits may be found in Table 2.


TOMOGONOPS AND NORTHWEST MIRAMICHI RIVER BASIN
N
TOMOGONOPS
HEATH STEELE MINES
2
SOUTH TOMOGONOPS
RIVER
3
PORTAGE
RIVER
HWY 430
LITTLE
RIVER
NORTHWEST
MIRAMICHI
RIVER
1
LEE
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BROOK
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TROUT
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5
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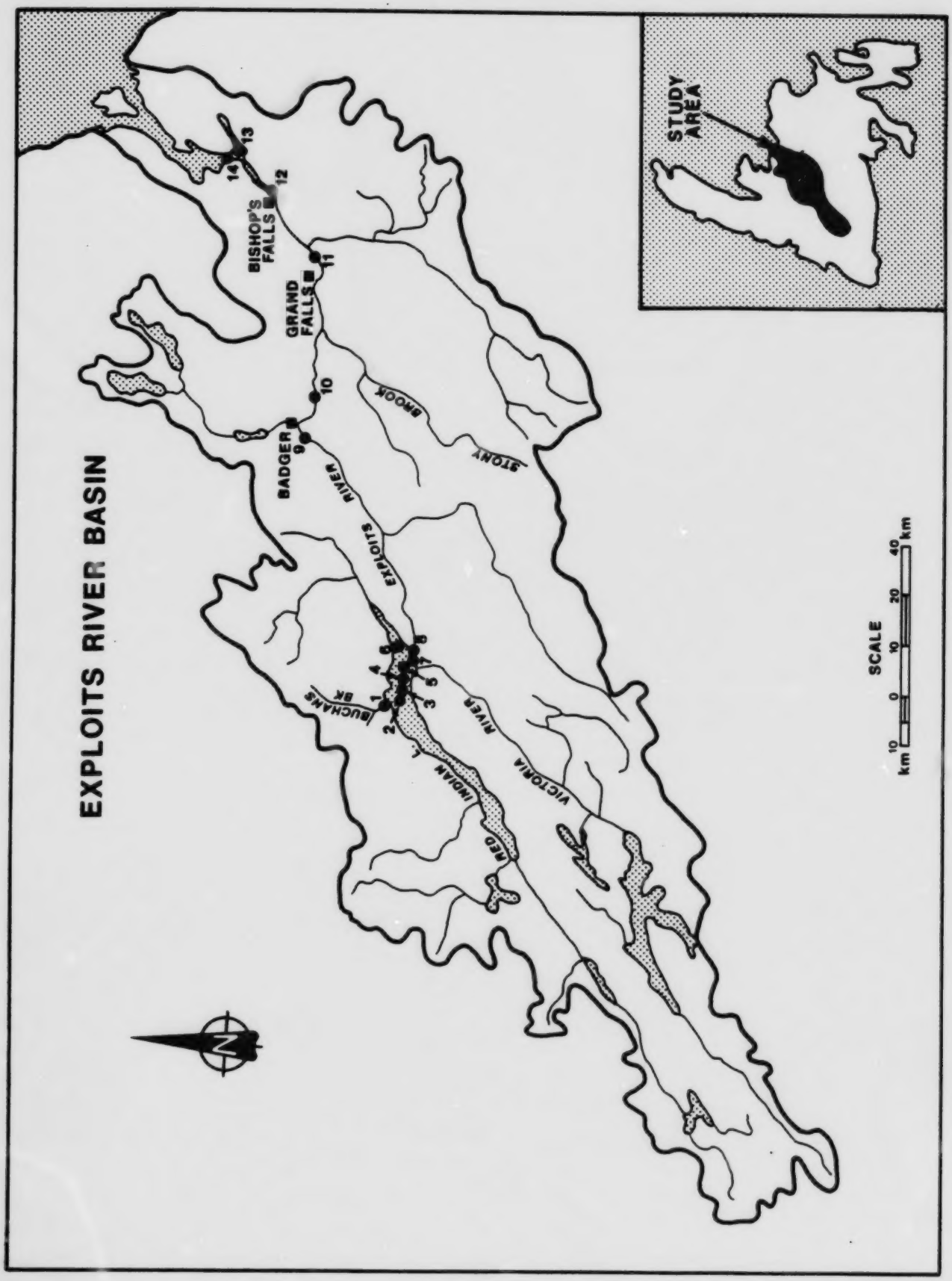
Figure 1


EXPLOITS RIVER BASIN
STUDY AREA
BISHOP'S FALLS
GRAND FALLS
BADGER
BUCHANS BK
EXPLOITS RIVER
STONY BROOK
INDIAN
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VICTORIA RIVER
SCALE
10 km 0 10 20 40 km
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Figure 2

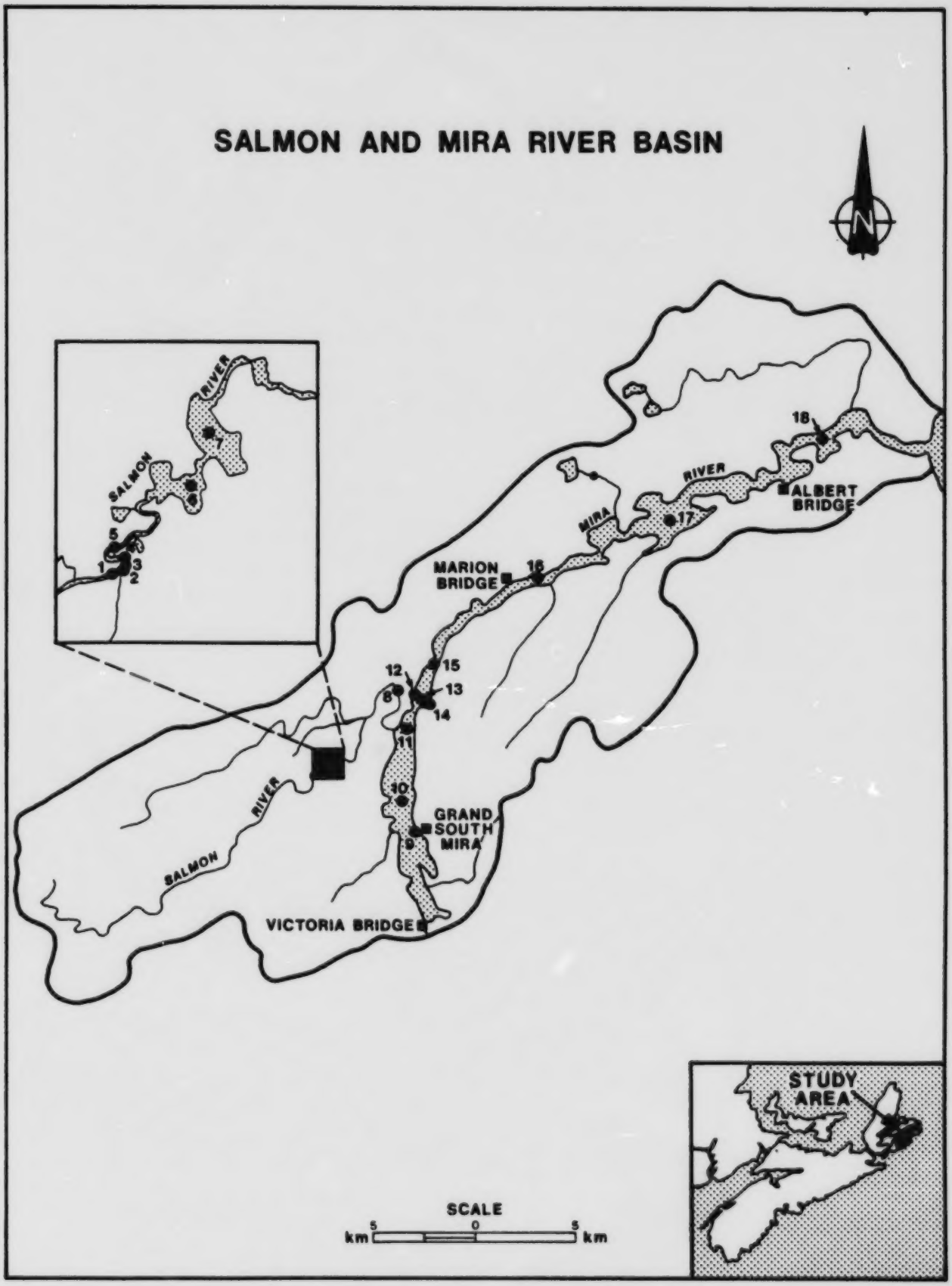
SALMON AND MIRA RIVER BASIN
N
SALMON RIVER
MIRA RIVER
ALBERT BRIDGE
MARION BRIDGE
GRAND SOUTH MIRA
VICTORIA BRIDGE
SALMON RIVER
STUDY AREA
SCALE
km 5 0 5 km

Figure 3

TABLE 2: PARAMETER CODES AND DETECTION LIMITS (mg/L)

	WATER		SEDIMENT		FISH	
	Parameter Code	D.L.	Parameter Code	D.L.	Parameter Code	D.L.
Aluminum	13305P	0.01	-	-	-	-
Arsenic	33007L	0.0005	33054L	0.05	33601L	0.001
Cadmium	48302P	0.001	48054L	0.1	48601L	0.01
Copper	29305P	0.002	29054L	0.2	29601L	0.20
Iron	26305P	0.05	-	-	-	-
Lead	82302P	0.002	82054L	0.5	82601L	0.05
Manganese	25304P	0.01	-	-	-	-
Mercury	-	-	80052L	0.02	80602L	0.02
Zinc	30304P	0.01	30054L	0.1	30601L	0.1
Carbon,T.Org.	-	-	06076L	5000.	-	-
Sand,percent	-	-	97281L	-	-	-
Silt,percent	-	-	97282L	-	-	-
Clay,percent	-	-	97283L	-	-	-
Lipid	-	-	-	-	99506L	-

D.L. = Detection Limit

2.3 Field Methodology

Surface water samples were collected directly into polyethylene bottles. In Red Indian Lake, depth samples were collected approximately one metre from bottom with a 2.0 L acrylic sampling bottle. Temperature and specific conductance were measured in situ at Red Indian Lake sites. Total water depth was also measured in the Exploits and Mira River sites.

In the Tomogonops/Northwest Miramichi River Basin sediment samples were collected with an aluminum shovel in a shallow backwater, of which the top 2 cm were sub-sampled. Three individual samples were collected and packaged in Whirl-pak [R] bags.

Bottom sediments in the Exploits and Mira River Basins were collected using a 22.5 x 22.5 cm stainless steel Ekman dredge. Once collected the sample was carefully released into a clean plastic tray. The top 2 cm was sub-sampled with a plastic scoop avoiding the edges of the sample, then was placed in a whirl-pak plastic bag and frozen immediately. In the Exploits River Basin three individual bottom samples were collected and packaged at each site. In the Mira Basin, additional sub-samples were taken at the 2-5 cm and the 5 to 8 cm levels. The sub-samples from each of three individual grabs were pooled in plastic bowls, thoroughly mixed and then packaged in Whirl-pak bags.

Large fish were collected using a 50 m by 3 m gill net with a 7.5 cm stretch mesh. In Red Indian Lake, the net was strung parallel to shore in 4 m of water about 100 m from shore. In the Mira River, the net was set in a small shallow bay. The fish were measured for fork and total length and weighed. Sex determination was also made. The fish were filleted and muscle tissue samples were packaged in whirl-pak bags.

Forage fish were collected in the Tomogonops/Northwest Miramichi River Basin. The fish were collected using a 6.5 m by 0.75 m hand seine with a 0.5 cm mesh. Shoreline drags of

25 m each were made until sample of sufficient size was collected to prepare three replicate samples of whole fish.

Samples were frozen immediately after field preparation. All water, sediment and fish samples were returned to the Water Quality Branch Laboratory in Moncton, N.B. for analysis.

2.4 Laboratory Methodology

Analyses were performed using standard analytical procedures described in the Analytical Methods Manual (Water Quality Branch, 1979).

The Water Quality Branch utilizes a non-residual method for metal determination in bottom sediments. This method uses 0.5 N HCl, a mild acid in relation to most extractable methods, to quantify the fraction of metal that is not part of the silicate matrix. This includes metal absorbed on sediment particles, complexed by and adsorbed on organic matter, and in the form of insoluble salts. To normalize the particle size distribution in the sediment, and consequently the metal content, the minus 80-mesh (<177 μm) portion of the sediment was analyzed (Lockerbie, 1987).

In a study when pooled with other "extractable" methods, the results produced by this method were biased low for

aluminum, copper, iron, and zinc. Cadmium and lead results were similar to other extractable methods (Cheam et al., 1987).

Mercury concentrations in bottom sediments were measured by an analytical method which involves the extraction of the inorganic forms of mercury with sulphuric acid, and the oxidation of organo-mercurials with potassium persulfate and potassium permanganate. This method has been proven reliable in ensuring total recovery of mercury from sediments of very high organic content.

To determine lipid content in fish, ten grams of sample are extracted with 2 x 100 mL portions of acetonitrile using an ultrasonic homogenizer. The extract is filtered through a 3-layer glass microfibre filter into a tared round-bottom flask. The solvent is removed on a rotary evaporator at reduced pressure and the weight of the residue determined as lipid.

3. RESULTS AND DISCUSSION

3.1 General Water Quality

Major ion, physical parameter and nutrient data for the three major basins are presented in Appendices II, III and IV.

As shown in these appendices, water chemistry was quite variable, from dilute, oligotrophic waters in the Exploits River Basin to areas of varying degrees of salt water influence in the Mira River.

In the Tomogonops/Northwest Miramichi River Basin, the Northwest Miramichi River at Hwy 430 above the confluence of the Tomogonops River is representative of background water quality. Increases in the levels of calcium, sulphate and specific conductance (Appendix I) at Wayerton, 14 km downstream of the confluence of the Tomogonops River are primarily the result of the mining activities in the Tomogonops River Basin.

The volcanic and granitic formations in the Exploits River Basin, like most of Newfoundland, give the Red Indian Lake and the Exploits River its characteristic water quality with low specific conductivity (22 to 27 microSiemen/cm) and corresponding low sum of dissolved constituents (13 to 14.8 mg/L) (Appendix II). Higher sulphate and calcium levels from

mine processing and treatment result in slightly higher values for Buchans Brook.

The Salmon/Mira River Basin data represent a single sampling of seventeen sites. The Salmon River data show that calcium and sulphate, probably attributable to the gypsiferous rock underlying the mine area (Montreal Engineering Company, 1972), and specific conductance decrease from the background station (Stn #1) to the lowermost station (Stn #8) 16 kilometres downstream at Salmon River Bridge. This is probably the result of dilution from tributaries draining areas with a granitic geology which surrounds the lead domain. The former mining operation, which had been deactivated and the site returned to near natural condition (less the forest cover) approximately three years prior to the survey, did not appear to influence the water quality.

The Mira River was influenced by salt water from its mouth to the uppermost sampling site, 4.5 km above the confluence of the Salmon River. The specific conductance ranged from 727 μS/cm at Grand South Mira to 29,600 μS/cm at Mira River Provincial Park.

3.2 Metals in Water

The metal data for all water sampling sites are presented in Appendices V, VI and VII. The metal data are also summarized by station or group of stations in Table 3.

The data sets varied from a single sampling in triplicate at Red Indian lake, Bay of Exploits, Salmon and Mira Rivers to three samples over a three day period on the Exploits River and the Tomogonops/Northwest Miramichi River Basin.

In order to put the data in Table 3 into perspective, it will be compared to water quality guidelines for the protection of aquatic life (Table 4), historical and current data. Since two of the basins support productive Atlantic Salmon (Salmo salar) populations, the data will also be compared to the Incipient Lethal Limit (ILL).

One ILL is defined as "that level of toxicity at which an organism can no longer survive for an indefinite period of time" (Sprague, 1964). For example by performing laboratory bioassays it has been found that for Atlantic Salmon, one ILL equals 0.048 mg/L and 0.600 mg/L for copper and zinc respectively. Morry and Cole (1977) report that 0.4 ILL of copper and zinc (0.014 mg/L or 0.170 mg/L) will cause an avoidance reaction in Atlantic salmon (i.e. block their upstream migration). Cumulative effects and water quality

TABLE 3: SUMMARY TABLE - RANGE OF METALS IN WATER (mg/L)

	Station	Aluminum	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Zinc
1	NW Miramichi R. at Hwy 430	0.06-0.11	-	L0.001	L0.002-0.005	0.10-0.14	L0.002-0.003	0.01-0.02	L0.01-0.01
2	S. Tomogonops R. at Hwy 430	0.11-0.20	-	L0.001	0.09-0.10	0.12-0.20	0.008-0.021	0.47-0.69	0.19-0.31
3	Tomogonops R. at mouth	0.18-0.28	-	L0.001	0.012-0.030	0.19-0.33	0.002-0.005	0.30-0.44	0.25-0.31
4	NW Miramichi R. at Wayerton	0.07-0.16	-	L0.001	0.003-0.006	0.20-0.21	L0.002-0.002	0.07-0.08	0.04-0.06
5	Buchans Bk	0.08-0.13	-	L0.001	0.009-0.012	0.22-0.35	0.015-0.045	0.03-0.04	0.25-0.44
6	Red Indian Lake (5 stn)	0.04-0.09	-	L0.001	0.002-0.007	L0.05-0.19	L0.002-0.009	L0.01-0.05	0.03-0.07
7	Exploits R. (5 stn)	0.05-0.07	-	L0.001-0.002	L0.002-0.003	0.03-0.08	L0.002-0.002	L0.01-0.03	0.02-0.03
8	Bay of Exploits (2 stn)	0.01	-	L0.001	0.002-0.003	0.12-0.28	L0.002-0.002	0.04-0.08	L0.01-0.26
9	Salmon R. (7 stn)	0.051-0.12	L0.0002	L0.001	L0.002	0.13-0.25	L0.002-0.007	0.04-0.27	L0.01-0.02
10	Mira R. (10 stn)	L0.01-0.049	L0.0002	L0.001	L0.002	0.05-0.15	L0.002	0.03-0.04	L0.01-0.02

which greatly influence the toxicity of metals, and sub-lethal effects are not considered. Therefore, these levels are considerably higher than the guidelines for copper and zinc in Table 4.

TABLE 4 – GUIDELINES FOR FRESHWATER AQUATIC LIFE AS TOTAL METALS (CCREM, 1987)

Parameter	Guideline	Comments
Aluminum	0.005 $mg.L^{-1}$	$pH<6.5$; $[Ca^{2+}]<4.0$ $mg.L^{-1}$; $DOC<2.0$ $mg.L^{-1}$
	0.1 $mg.L^{-1}$	$pH\geq6.5$; $[Ca^{2+}]\geq4.0$ $mg.L^{-1}$; $DOC\geq2.0$ $mg.L^{-1}$
Arsenic	0.05 $mg.L^{-1}$	
Cadmium	0.2 $\mu g.L^{-1}$	Hardness 0–60 $mg.L^{-1}$ ($CaCO_3$)
	0.8 $\mu g.L^{-1}$	Hardness 60–120 $mg.L^{-1}$ ($CaCO_3$)
	1.3 $\mu g.L^{-1}$	Hardness 120–180 $mg.L^{-1}$ ($CaCO_3$)
	1.8 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}$ ($CaCO_3$)
Copper	2 $\mu g.L^{-1}$	Hardness 0–60 $mg.L^{-1}$ ($CaCO_3$)
	2 $\mu g.L^{-1}$	Hardness 60–120 $mg.L^{-1}$ ($CaCO_3$)
	3 $\mu g.L^{-1}$	Hardness 120–180 $mg.L^{-1}$ ($CaCO_3$)
	4 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}$ ($CaCO_3$)
Iron	0.3 $mg.L^{-1}$	
Lead	1 $\mu g.L^{-1}$	Hardness 0–60 $mg.L^{-1}$ ($CaCO_3$)
	2 $\mu g.L^{-1}$	Hardness 60–120 $mg.L^{-1}$ ($CaCO_3$)
	4 $\mu g.L^{-1}$	Hardness 120–180 $mg.L^{-1}$ ($CaCO_3$)
	7 $\mu g.L^{-1}$	Hardness >180 $mg.L^{-1}$ ($CaCO_3$)
Manganese[1]	0.02 $mg.L^{-1}$	
Zinc	0.03 $mg.L^{-1}$	

1 – Guideline for marine aquatic life (McNeely, et al, 1979)

The guidelines established by the Canadian Council of Resource and Environment Ministers (CCREM, 1987) are much more restrictive as compared to those previously recommended by the Environmental Studies Board in 1973 and the Great Lakes Water Quality Branch in 1976 (McNeely et al, 1979). Guidelines for copper and lead have been reduced 60 to 500 percent respectively at low hardness levels to reflect recent studies which have shown increases in metal toxicity as hardness decreases.

According to Table 3, arsenic was not detected in 10 samples analyzed in the Salmon/Mira River Basin. Cadmium was found at near detection limit levels in 7 of 149 samples. The seven positive values were found in samples from one site, Exploits River, 0.6 km below Millertown Dam. Cadmium, although not detected in most samples using our methods, at trace levels may have an adverse effect on fish. The suggested guideline for the protection of aquatic life is 0.0002 mg/L (Table 3), five times lower than the detection limit of this study.

Also according to Table 3, only three stations have elevated levels of toxic metals which would be detrimental to aquatic life and perhaps cause an avoidance reaction in the upstream migration of Atlantic salmon (ILL = 0.4). These stations are South Tomogonops River at Hwy 430, Tomogonops

River at mouth in New Brunswick and Buchans Brook in Newfoundland.

The metal levels determined at the two Tomogonops sampling sites (Table 3) were not unexpected. The South Tomogonops River at Hwy 430 sampling site was approximately 3 kilometres below the tailings area which receives treated process effluent, mine water and surface drainage. In addition to the above input, the sampling station at the mouth of the Tomogonops River also receives input from the Little South Tomogonops River which contained high levels of copper and zinc (Heath Steele, 1984).

The Tomogonops River station with median levels of 0.030 mg/L copper and 0.26 mg/L zinc greatly exceed the water quality guidelines for the protection of aquatic life of 0.002 mg/L copper and 0.03 mg/L zinc (CCREM, 1987). The ILL of 0.4 (0.014 mg/L copper or 0.170 mg/L zinc) was also exceeded.

The background station established on the Northwest Miramichi River at Hwy 430 and above the confluence of the Tomogonops River, had copper, lead and zinc values which were either below or at the detection limits. Fourteen kilometres downstream at the Northwest Miramichi at Wayerton copper and zinc values were slightly higher than above the confluence of the Tomogonops River with median values of 0.004 and 0.05 mg/L respectively. Lead values remained below the detection limit.

Dilution by the much larger Northwest Miramichi River probably accounts for the reduced metal levels.

Metal data are generated weekly by Heath Steele Ltd. at a number of sites on the mine property as well as for the South Tomogonops River at Hwy 430 and the Northwest Miramichi River at Wayerton. The river sites were sampled by Heath Steele and Water Quality Branch (WQB) on June 19, and values for copper and zinc are virtually identical suggesting that the data sets seem comparable (Table 5). This agreement also applies to Wayerton samples for yearly Heath Steele and WQB monitoring data.

Data from short term surveys can be misleading. For example, the zinc values during the survey on the South

TABLE 5: METAL VALUES IN mg/L AT COMMON SAMPLING SITES - WQB SURVEY AND HEATH STEELE MINES - 1984

	Copper	Lead	Zinc
South Tomogonops at Hwy 430			
June 19 (WQB Survey)	0.10	0.020	0.31
June 19 (H.S. Monitoring)	0.087	0.095	0.303
Jan-June (H.S. - Mean)	0.094	0.131	1.39
July-Dec. (H.S. - Mean)	0.069	0.105	0.233
Northwest Miramichi at Wayerton			
June 19 (WQB Survey)	0.005	-	0.04
June 19 (H.S. Monitoring)	0.006	-	0.052
Jan-June (H.S. - Mean)	0.005	-	0.052
July-Dec. (H.S. - Mean)	0.002	-	0.024
Jan-Dec. (H.S. - Mean)	0.004	-	0.044
Jan-Dec. (WQB Monitoring-Mean)	0.004	-	0.048

Tomogonops were relatively low with a survey mean of 0.24 mg/L, however the Heath Steele mean for January to June 1984 was 1.38 mg/L due to high values during spring runoff in April of 2.3 to 2.8 mg/L. Values of 4.4 and 4.45 mg/L were also reported in May during declining flows. Monthly means for zinc in April and May were 1.29 and 2.65 mg/L respectively (Heath Steele, 1984). The zinc values were much lower during the last six months with a mean of 0.233 mg/L (Heath Steele, 1984) probably the result of fewer rain events and subsequent runoff. The zinc values at Wayerton also reflected the high levels determined on the South Tomogonops. From April 11 to June 19, zinc values ranged from 0.052 to 0.123 mg/L zinc with a mean of 0.073 (Heath Steele, 1984). Similarly, the mean copper and zinc levels were twice as high during the January to June period as compared to July to December (Table 5).

From an historical perspective, the yearly means of zinc and copper determined by Fisheries Research Board from 1962 to 1973 are presented in Table 6. The sites on the Northwest Miramichi River at Miners Bridge and Wayerton-Curventon represent sections of the river above and below the confluence of the Tomogonops River.

Prior to a program to control site drainage (1969-1971) copper and zinc values greatly exceeded the present day water quality guidelines and often exceeded the ILL of 0.4 based on the yearly mean. The yearly mean is quite misleading since

high levels of copper and zinc were often associated with rain events. For example in 1965, zinc and copper levels exceeded 0.500 mg/L and 0.040 mg/L on four occasions (Sprague and Carson, 1966).

TABLE 6: YEARLY AVERAGES (mg/L) FROM SAMPLING IN THE NORTHWEST MIRAMICHI

	N.W. Mir. @ Miner's Bridge			N.W. Mir.@ Wayerton-Curventon		
	Zn	Cu	# samples	Zn	Cu	# of samples
1962	0.003	0.003	26	0.110	0.015	52
1963	0.003	0.001	51	0.150	0.022	51
1964	0.003	0.001	52	0.200	0.021	52
1965	0.001	ND	52	0.210	0.021	52
1966	0.002	ND	51	0.210	0.018	51
1967	0.003	ND	52	0.240	0.020	52
1968	0.002	ND	51	0.130	0.012	51
1969	0.001	0.001	51	0.140	0.015	51
1970	0.001	0.001	13	0.115	0.012	12(2)
1971	0.004	0.003	12	0.074	0.006	12(2)
1972	0.002	0.001	12	0.035	0.004	12(2)
1973	0.002	ND	12	0.027	0.003	12(2)

1: Carson, 1974
2: Yearly average, calculated from Monthly Average

After completion of the control program for site drainage, copper and zinc values at Wayerton decreased in 1972-1973 (Table 6) to levels near the present day water quality guidelines.

Mean values at Wayerton for copper (0.005 mg/L) and zinc (0.05 mg/L), during the 1984 survey as well as the yearly means for the WQB Overview Monitoring Program (Table 5) and the Heath Steele Monitoring (Table 5), indicate copper and

zinc levels have changed little since 1972-73 and although slightly exceeding the water quality guidelines should not be detrimental to aquatic life or the migration of Atlantic Salmon.

The third station with elevated levels of copper and zinc was Buchans Brook, an inflow stream of Red Indian Lake and the receiving stream for tailings from ASARCO mining operations at Buchans. The copper (0.009-0.012 mg/L) and zinc (0.25-0.44 mg/L) values for Buchans Brook greatly exceeded the water quality guidelines of 0.002 and 0.03 mg/L respectively. Zinc also exceed the ILL of 0.4 (0.170 mg/L Zn) which would prevent upstream migration of Atlantic Salmon. The copper and zinc values at Buchans Brook were slightly higher in 1984 as compared to Morry and Cole (1977). The 1984 values given in Table 7 are extractable values versus dissolved values for previous years, however the turbidity was low at 0.6 JTU which suggests that there may be little difference between the dissolved and extractable values.

TABLE 7: COMPARISON OF COPPER AND ZINC VALUES IN WATER AT BUCHANS BROOK (mg/L)

	1966[1] (Diss.)	1970[1] (Diss.)	1974[1] (Diss.)	1984 (Ext.)
Cu (Mean)	0.040	0.012	0.003	0.010
Zn (Range)	0.450-0.550	0.450-0.550	0.050-0.33	0.25-0.44

1 - Morry and Cole (1977); Diss = Dissolved, Ext = Extractable

As was observed in the Tomogonops River metal levels also appear to increase during rain events in Buchans Brook. A rain event on July 28 resulted in noticeably increased flow as well as increased copper and zinc values probably as a result of runoff from tailings near the mine site. Zinc nearly doubled from 0.25 to 0.44 mg/L while copper increased slightly from 0.009 to 0.012 mg/L. The 1974 data given in Table 7 represent fourteen samples collected during a four day period. On other occasions during the 1974 survey, dissolved zinc values reached 0.540 mg/L.

Lead values in Buchans Brook which ranged from 0.015-0.45 mg/L exceeded the CCREM (1987) guideline of 0.001 mg/L. The values on July 29 decreased with increased flow suggesting that the lead is associated with the geological structure rather than the mine operations.

Copper, lead and zinc values at Red Indian Lake stations were much lower than in Buchans Brook. Although they are slightly above the present water quality guidelines, the copper and zinc values are well below the ILL of 0.4 suggesting the safe passage of Atlantic Salmon through Red Indian Lake, with completion of the fishway at Millertown Dam. The concentrations of copper and zinc in the lake differed little from those reported by Morry and Cole (1977) with the

exception of a few higher copper values in the plume from Buchans Brook in 1974.

In 1984, water samples were collected at the surface and approximately one metre from the bottom. The data for the five lake stations (Appendix VI) indicate little difference in metal concentration between the surface and bottom even though the bottom samples were collected in close proximity to metal contaminated sediment (see Section 3.2). This may indicate limited activity, such as methylation at the water-sediment interface, therefore there has been little or no release of metals back into the water phase. From their data, Morry and Cole (1977) also suggested that harmful concentrations were seldom leached from the sediment.

Copper, lead and zinc values for samples from Exploits River stations and the two estuary sites were at their respective detection limits and water quality guidelines. Recent data from a monitoring station on the Exploits River at Grand Falls substantiate the survey data. The yearly ranges and means for the Grand Falls monitoring station are presented in Table 8. The monthly data used to formulate Table 8, also indicates little variation or seasonal change in the metal data (Appendix IX).

According to Table 2 and Appendix VII, metals were either not detected or at low levels in water samples from

Salmon/Mira River Basin. All samples met the water quality guidelines with a few minor exceptions. Toxic metals such as arsenic, cadmium, copper and mercury were not detected in any samples in the Basin. Mean lead (0.007 mg/L) and zinc (0.025 mg/L) values were found in the Salmon River at the center of a stagnant cove immediately below the former discharge stream, however, they were not detected in the river below the cove. Manganese levels were five times higher in the cove as compared to the background station however they did not influence the river below the cove. In 1981, Westlake and Smith found higher levels of lead (0.14 and 0.13 mg/L) but only in the discharge stream. They found no zinc in 1981.

TABLE 8: EXTRACTABLE COPPER AND ZINC (mg/L) AT GRAND FALLS NFLD - 1967 TO 1985 FROM IHD AND WQB OVERVIEW MONITORING PROGRAMS

	Copper			Zinc		
Year	Samples	Range	Mean	Samples	Range	Mean
1967	2	<0.01-0.02	0.01	2	0.18-0.20	0.19
1968	6	<0.01-0.07	0.02	8	0.05-0.16	0.11
1969	6	0.02-0.08	0.05	7	0.04-0.14	0.09
1970	5	<0.01-0.05	0.02	5	0.07-0.10	0.09
1971	4	0.01-0.16	0.05	4	0.06-0.10	0.08
1972	5	<0.002-0.007	0.003	5	0.037-0.100	0.060
1973	4	<0.002-0.005	0.003	4	0.032-0.050	0.041
1974	2	0.002-0.005	0.004	2	0.040-0.050	0.045
1975		NO DATA			NO DATA	
1976	2	<0.002	-	2	0.030	-
1977	4	0.002-0.030	0.011	4	0.026-0.080	0.044
1978	4	<0.002-0.008	0.004	4	0.016-0.029	0.024
1979	5	<0.002-0.003	<0.002	5	<0.002-0.028	0.019
1980	6	0.002-0.003	0.002	6	0.019-0.036	0.025
1981	10	0.002-0.003	0.003	10	0.012-0.031	0.024
1982	11	0.002-0.004	0.002	11	0.02-0.04	0.03
1983	11	0.002-0.006	0.003	11	0.02-0.06	0.03
1984	11	0.002-0.004	0.002	11	0.010-0.030	0.018
1985	5	0.002-0.003	0.002	5	0.010-0.025	0.015

Though incomplete, monitoring data from a station on the Salmon River at Salmon River Road, indicate there was no increase in metal levels during the latter stages of the mine's operation as compared to pre-mining period (Appendix X).

The highest levels of aluminum, iron and manganese were found at the two Tomogonops River stations. Aluminum and iron values slightly exceeded their respective water quality guidelines at these sites. No guidelines for aquatic life were given by CCREM (1987) for manganese. As with iron, manganese is an essential element for the nutrition of both human and animals, and is rarely a problem in freshwater (Weiner and Giesy, 1979).

3.3 Metals in Bottom Sediments

Bottom sediments were collected at all sites except those rivers with a rock and gravel substrate such as the Northwest Miramichi and Exploits River. Bottom sediment data are found in Appendices XI and XII and are summarized in Table 9.

One triplicate sample was collected in the Tomogonops/ Northwest Miramichi River Basin at the South Tomogonops River at Hwy 430. The sample was collected in a backwater area above the highway culvert. The samples were composed of sediments and detritus (as evident by the high mean organic

TABLE 9: SUMMARY TABLE - RANGE OF METALS* IN BOTTOM SEDIMENTS (mg/kg)

	Aluminum	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Mercury	Zinc	TOC
1 South Tomogonops R.	-	146	9.7	2700	-	3000	-	0.19	2900	603,000
2 Red Indian Lake (5 sites)	-	100-196	3.2-6.9	306-360	-	1900-2600	-	0.42-0.92	680-1170	73,600-274,000
3 Bay of Exploits (2 sites)	-	10-14	2.0	39-55	-	200-300	-	0.26-0.44	200-270	486,000-526,000
4 Salmon R. (7 sites)	400-800	1.49-6.43	0.12-7.3	3.0-9.2	5900-1400	25-2630	290-5400	0.02-0.16	29-800	21,000-83,000
5 Mira R. (10 sites)	5000-11000	1.97-18.97	0.12-2.10	9.3-13.7	12000-34000	29-124	230-16000	0.08-0.21	63-180	52,000-131,000

* Mean of triplicate samples

carbon content of 603,000 mg/kg), and although not representative of the basin it does provide some indication of the distribution of metals released from the mines tailings area, approximately 3 kilometres upstream. The adverse effects of the metals in the sediments is probably negligible compared to the metal load in the water itself.

In the Exploits River Basin, bottom sediments were collected at five stations in Red Indian Lake and two stations in the Bay of Exploits near the mouth of the Exploits River. Due to the unavailability of sediments in the littoral zones during the 1984 Survey, all Red Indian Lake samples were collected near the center of the lake. Because of the unusual structure of these sediments, particularly the visible stratification, field description of these sediments are given in Appendix XII.

In Red Indian lake where deposition of metals to the lake sediments has spanned 57 years, excessive levels of metals were found in the bottom sediments (Table 9). The reddish-brown fan of mine tailings entering from Buchans Brook during the 1974 survey of Morry and Cole (1977) were distributed throughout the lake with levels of 1500 mg/kg copper and 3000 mg/kg zinc found as far as 40 kilometres from Buchans Brook. During the same 1974 survey, core samples indicated a tailings depth of more than 105 mm in the vicinity of Buchans Brook, decreasing with distance from the Brook. At

a distance of 4 km east of Buchans Brook, the tailings depth was 45 mm.

Morry and Cole (1977) described the benthic community in Red Indian Lake as "depauperate". They felt that in some areas that it was in part due to the unsuitable nature of the tailings covered bottom, however the lack of species diversity and abundance were common to other areas of the lake therefore they considered the generally unproductive nature of the lake to be the overriding factor.

TABLE 10: SUMMARY TABLE - MEAN METAL VALUE IN RED INDIAN LAKE AND BAY OF EXPLOITS BOTTOM SEDIMENTS (mg/kg)

Station	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc	TOC
2	163	6.2	306	1900	0.88	910	73,600
3	196	4.1	310	2000	0.92	700	93,000
4	140	3.2	330	2500	0.59	680	113,000
5	140	4.2	360	2600	0.54	870	134,000
6	100	6.9	310	2400	0.42	1170	274,000
13	10	2.0	39	200	0.44	200	526,000
14	14	2.0	55	300	0.26	270	486,000

The five sites samples in 1984 followed a ten kilometre axis, west to east, from Buchans Island to the community of Millertown. The elevated levels of metals as noted earlier were excessive, as compared to down core values determined by Morry and Cole (1977), of 10 to 50 mg/kg for copper, <10 to 40

mg/kg for lead and 60-200 mg/kg for zinc. However, as a general comparison the 1984 data differs dramatically with respect to lead and zinc values. Lead values were much higher in 1984 whereas 1984 zinc values were very low in relation to 1974 values. The non-residual method used in 1984 has been shown to be biased low for zinc as compared to extractable methods as discussed under laboratory methodology.

The high levels in sediments are to be expected given that the metals associated with the mine tailings would settle quickly in the quiescent lake water, but also the sorption processes to the bottom sediments dominate the fate of most metals in water (Callahan et al., 1979). The particle size analysis in Table 11 indicates that the silt-clay fraction accounted for 91.1 to 99.2 percent of the bottom material at the sample sites. This fraction is important in the sorption processes.

TABLE 11: MEAN PARTICLE SIZE ANALYSIS OF RED INDIAN LAKE SEDIMENTS

Station	Sand (%)	Silt (%)	Clay (%)
2 (2)[a]	2.0	73.	25.
3 (2)	0.8	73.9	25.3
4	4.8	71.9	24.3
5 (3)	5.5	73.1	23.4
6 (3)	8.9	68.5	22.6

a - number of samples analyzed

Whereas some metals may be remobilized by micro-organisms as in the case of methylation of lead and mercury, other metals such as copper may be so kinetically inhibited as to be almost nonlabile (Callahan et al., 1979). However, the lack of benthic organisms and the generally unproductive waters of the lake would probably be the controlling factor related to methylation processes and remobilization of metals.

The total organic carbon (TOC) values in Table 10 increased with distance from Buchans Brook. This may suggest a larger percentage of tailings were present in the samples nearer Buchans Brook, however higher metal levels as would be expected were not found, nor does the particle size analysis (Table 11) support this. Morry and Cole (1977) described the tailings as "characteristically sandy and granular" which would likely increase the sand fraction. The higher TOC may be attributed to other anthropogenic activities such as forestry operations, log-driving and saw mills. Decayed sawdust was observed in samples near Millertown.

The metal levels in the Bay of Exploits samples (Table 9) are much lower than those in Red Indian Lake, however in most cases they remain above background levels, especially cadmium and mercury. The metals in the Bay of Exploits probably result from the transport of metal-laden suspended material scoured from Red Indian Lake during spring break-up.

A summary table of mean metal values at the 18 stations sampled in 1985 in the Salmon/Mira River Basin is provided in Table 12. The remaining metals data for iron, manganese and aluminum, and particle size analysis are given in Appendix XII.

Salmon River sediments collected in a cove downstream of the effluent inflow had metal levels 2 to 37 times higher than those collected at the background site on the Salmon River. Lead values increased from 69 mg/kg at the background site to 2630 mg/kg (mean of triplicate split samples) near the centre of cove. Zinc, cadmium and manganese increased 12 to 13 times and arsenic, copper, mercury, iron and aluminum levels increased somewhat less (x2-3). Approximately 500 m below the cove, the metal levels had returned to background levels or slightly above. Metal concentrations increased again in the sediments of two shallow flow-through ponds 1.5 kilometres below the effluent stream whereas fifteen kilometres downstream at the Salmon River Road monitoring station, the concentrations of most metals were well below levels at the background station.

Westlake and Smith (1983) surveyed the Salmon River in the vicinity of Java Mines in 1981. Metal concentrations at similar sampling stations and for common parameters are given in Table 13. Given the extreme spatial variability Westlake

and Smith (1983) encountered in the cove itself, different sampling and sub-sampling techniques and laboratory methodologies (total metals in 1981 versus non-residual metals in 1985) meaningful comparison and interpretation of the data are virtually impossible.

Based on the 1985 data, toxic metals such as lead and cadmium remain at elevated levels in the cove and the two small ponds even six years after closure of the mine. The small amount of sediment found at the river stations indicates that the sediments are being scoured during spring runoff, however due to the configuration of the river, the cove and ponds must be less subject to the scouring action.

The Mira River, at the confluence of the Salmon River, is a lake-like basin and an excellent settling area for sediments and tailings transported down its major tributary. Dark grey tailings material was observed in the quiescent area of the Salmon River above its confluence with the Mira River and also formed a delta area extending 50-100 m into the Mira.

TABLE 12: SUMMARY TABLE - MEAN METAL VALUES IN SALMON/MIRA RIVER BASIN SEDIMENTS (mg/kg)

Station	Sub Sample (cm)	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc	TOC
SALMON								
1	0-2	1.71	0.60	3.0	69.	0.02	63.	21000
2	0-2	6.43	7.3	8.0	2150.	0.06	800.	77000
3	0-2	3.01	5.3	9.2	2630.	0.08	700.	54000
5	0-2	1.94	0.81	3.0	120.	0.03	88	60000
6	0-2	2.35	1.80	5.5	470.	0.11	168.	83000
7	0-2	3.69	2.3	7.2	520.	0.16	200.	101000
8	0-2	1.49	0.12	3.6	25.	0.04	29.	25000
MIRA								
9	0-2	7.49	1.9	13.7	99.	0.21	173.	63000
	2-5*	2.74	1.5	15.0	73.	0.18	170.	65000
	5-8*	2.63	2.0	15.0	71.	0.16	170.	71000
10	0-2	8.19	2.1	13.0	117.	0.19	170.	66000
	2-5	4.63	1.5	14.0	101.	0.14	190.	64000
	5-8	4.00	1.1	13.0	85.	0.14	160.	67000
11	0-2	3.67	0.8	9.7	109.	0.15	120.	53000
	2-5	2.63	0.9	11.0	101.	0.16	120.	52000
	5-8	2.07	0.8	10.0	91.	0.13	120.	54000
12	0-2	3.50	1.4	10.0	124.	0.17	190.	56500
	2-5	2.20	1.6	10.0	100.	0.12	210.	54000
	5-8	1.83	1.6	10.0	90.	0.15	190.	58000
13	0-2	3.87	0.9	10.0	118.	0.16	160.	63000
	2-5	2.61	1.0	12.0	109.	0.14	210.	65000
	5-8	4.66	1.0	9.6	106.	0.15	200.	66000
14	0-2	3.05	0.9	9.3	120.	0.13	180.	52000
	2-5	1.48	1.0	10.0	100.	0.12	150.	53000
	5-8	1.78	1.0	10.0	93.	0.10	130.	42000
15	0-2	1.97	1.8	9.6	99.	0.15	180.	81000
	2-5	2.53	2.0	8.0	91.	0.13	200.	88000
	5-8	2.17	2.0	8.0	83.	0.14	190.	86000
16	0-2	5.77	1.7	7.7	56.	0.09	177.	131000
	2-5	6.99	1.9	4.0	56.	0.11	190.	165000
17	0-2	19.0	0.85	11.0	63.	0.13	180	98600
	2-5	9.65	0.80	10.0	59.	0.12	200.	105000
	5-8	10.60	0.90	7.0	51.	0.14	200.	127000
18	0-2	6.42	0.3	12.0	29.	0.08	63.	72500
	2-5	6.93	0.2	14.0	31.	0.05	70.	70000
	5-8	6.46	0.6	11.0	31.	0.06	70.	72000

* Single value only for 2-5, 5-8 cm samples

The sampling methodology for the Mira River included sub-surface sediment analysis of layers representing the 2 to 5 cm and 5 to 8 cm vertical depth to determine if the river sediments had been recently enriched or if the values found represent background levels.

TABLE 13: METAL CONCENTRATIONS IN SEDIMENTS (mg/kg) FOR SIMILAR SAMPLING STATIONS ON THE SALMON RIVER IN 1981 AND 1985

Station Ident.	Date	Copper	Lead	Zinc	Cadmium	TOC
S-3-2-C	1981	-	-	-	-	-
1	1985	3.0	69.	63.	0.6	7200
S-3-2-A	1981	22.8	4178.	558.	3.8	18169
2	1985	8.0	2150.	800.	7.1	12000
S-3-3-B	1981	14.6	18078.	472.	2.3	21048
3	1985	9.2	2630.	700.	5.3	11700
S-2	1981	1.7	48.	63.	1.2	5603
4	1985	3.0	120.	89.	0.8	7100
S-1	1981	5.8	215.	161.	1.2	14376
5	1985	7.2	520.	200.	2.3	14300

As was determined in Red Indian Lake, the tailing fines were also widely distributed in the Mira River. The stations chosen above the confluence of the Salmon River to depict background conditions had higher metal levels than the downstream sites. Therefore other than the enrichment of surface sediments with respect to sub-surface sediments values, the influence of the Salmon River and the mine was difficult to ascertain.

According to Table 12, the "priority" metals which were enriched as a result of the mining operation included arsenic and lead with levels however representing just a fraction of those found in Red Indian Lake. Manganese was also strongly enriched. (Appendix XII).

Arsenic and lead levels were found to be much greater in the stagnant cove than at the background site on the Salmon River. Although their presence is not as dramatic in the Mira River, enrichment of sediments, especially in the upper basin, has occured. Enrichment of arsenic was the highest at the two sites above the confluence of the Salmon River and decreased at the downstream sites. The highest concentration of arsenic was at Sangaree (19.0 mg/kg), where the river forms a large basin and a natural depository for particulates. With the exception of the Sangaree station, the arsenic levels in the Mira River fall within the range of 3 to 15 mg/kg which Crecelius et.al. (1975) considered background levels in Puget Sound. Arsenic levels in Great Lake sediments ranged from 0.5 to 14 mg/kg (Traversy et.al. 1975).

Lead concentrations in the Mira River sediments were quite uniform for the upper seven sites (upper basin) ranging from 99 to 124 mg/kg. The levels of lead have not increased dramatically over what may be considered background as determined from the sub-surface layers. The 0-2 cm surface

layer had mean lead values of 17% (range 8 to 36 %) higher than the 2 to 5 cm layer. It should be noted that the natural increase of lead in the older sediment, that is the 2 to 5 cm layer as compared to the 5 to 8 cm layer had a mean of 9% (range 3 - 19%). The high background levels are probably a function of natural deposition from the lead rich deposits found in the Salmon River Basin.

The metal values in the Mira River sediments are very low in comparison to the Tomogonops or Red Indian Lake samples. However, the mine was only operational for approximately 1.5 years and though the deposition of lead in the Mira River was accelerated the mine did not operate long enough to make such an impact on the sediments. In the authors opinion, the metals values in sediments have been diluted as a result of using standard sampling practices. If the period of operation and the years between closure and sampling had been taken into account, perhaps we could have shown greater enrichment in a 0 - 1 cm sub-sample and hence higher levels potentially available to biota.

Manganese was abundant in the bottom sediments of the Mira River with mean values ranging from 1170 to 16,300 mg/kg at seven stations sampled in the upper basin (Appendix XII). Manganese was 12 times higher in the cove than at the background station on the Salmon River, however in the Mira River, the values were only 1 to 4 times background values.

A literature search revealed few papers with discussions of manganese in bottom sediments, however it was observed that levels in the Mira River, whether natural or enriched were very high. Manganese is relatively non-toxic to aquatic biota and is seldom a problem in freshwaters (Weiner and Giesy, 1979). It should also be noted that large manganese nodules (5 cm in diameter) were plentiful in sediment grabs at station 14 on the Mira River.

3.4 Metals in Biota - Fish

The purpose of the surveys was not only to determine metal levels present in water and sediment but to attempt to determine what effects these levels could have on aquatic life. Fish are at the top of the trophic level thus they are excellent organisms to provide information on bioavailability and bioconcentration up the food chain.

Metal data in fish samples for all basins is presented in Appendix XIV with data for selected metals summarized in Table 14. The physical description of fish samples is given in Appendix XV.

In the Northwest Miramichi River Basin, forage fish were collected as indicators of bioaccumulation for several reasons. They are site specific, therefore would best represent the

TABLE 14: SUMMARY TABLE - RANGE OF SELECTED METALS IN FISH (mg/kg - wet weight)

Basin Species		Arsenic	Cadmium	Copper	Lead	Mercury	Zinc	Lipid
NW Tomogonops/Miramichi								
Lake Chub *		0.067	0.080	1.3	0.063	0.085	81.	2.57
Exploits - Red Indian Lake								
Land-locked Salmon	(6)	L0.001	L0.02-0.05	0.32-0.47	0.07-0.15	0.24-0.62	6.0-12.0	1.45-2.64
Salmon/Mira								
Longnose Sucker	(6)	L0.001	L0.01	0.57-1.9	0.07-0.14	0.034-0.20	3.6-5.1	-
White Perch	(2)	L0.001	L0.01-0.085	0.82-1.7	0.15-0.20	0.50-0.53	5.9-6.4	-

* mean of triplicate

unconfined study area, uniform in age, and representative of the year of capture. In the Basin, the availability of forage fish, in this case lake chub (Couesius plumbeus), was limited to a backwater area on the Northwest Miramichi River at Wayerton. Individuals ranging in length from 35 to 55 mm were randomly divided and analyzed as triplicate samples.

According to Table 14, concentrations of cadmium, lead and mercury were slightly above the detection limit. Arsenic, though three times the detection limit fell within the range of 0.03 - 0.12 mg/kg that Traversey et.al.,(1975) found for arsenic in Great Lakes fish.

Copper and zinc are essential nutrients and are readily bioaccumulated by fish (Callahan, et al., 1979). Copper and zinc in the forage fish had mean levels of 1.3 and 81. mg/kg (wet weight), respectively. The copper values are similar to those found for small fish analyzed whole from the Great Lakes by Lucas et al. (1970), however the zinc levels (mean - 81 mg/kg) greatly exceed the normal range of concentrations of zinc in fish of 4 to 20 mg/kg (wet weight) (Spear, 1981).

Zinc is readily accumulated by freshwater fish from both food and water (Calhahan, 1979). In a study using sticklebacks (Gasterosteus aculeatues) there was strong evidence that the main route of uptake was through the gills (Taylor et. al., 1980). This may partially explain the high body burdens of zinc

at Wayerton, although being an essential nutrient, fish are normally able to regulate to a large degree the uptake and excretion of zinc (Sloterdijk, 1985). Heath Steele monitoring data at Wayerton (Appendix VIII) for 1984 indicate a mean value of 0.048 mg/L zinc, one and a half times the guidelines for the protection of aquatic life of 0.03 mg/L zinc. The bioconcentration factor for freshwater fish reported by Callahan et. al., (1979) is 1000, which would require that the zinc concentration in water would be 0.081 mg/L. As noted previously, the Heath Steele data did indicate a mean of 0.073 mg/L for the 10 weeks preceding the survey.

Laboratory studies have shown harmful effects of zinc or zinc- metal mixture on fish and other aquatic organisms to occur over the range of about 0.030 to 0.200 mg/L (Taylor et. al., 1980).

In the Exploits River Basin, the catch/effort in Red Indian Lake was even poorer than Morry and Cole (1977) had described in 1974. Only two specimens were netted during a 72-hour period.

With the cooperation of Fisheries and Oceans in St. John's, four additional specimens were obtained from the same area. The fish were all land-locked salmon (Salmo salar) or ouananiche which Morry and Cole (1977) determined to be the dominant species of the lake both in abundance and biomass during their 1974 survey. The six fish measured 34 to 40 cm in length with a

mean length of 38 cm and a mean weight of 460 grams (Appendix XV). According to the age length distribution for ouananiche based on 231 fish caught by Morry in 1974, these six fish would probably fall in the 8^{+} to 9^{+} year old class. The age/length relationship of the Red Indian Lake ouananiche was much lower than similar oligotrophic lakes in Labrador (Bruce et. al., 1979). Morry and Cole (1977) found within the benthic community a lack of species diversity and abundance which demonstrates the unproductive nature of Red Indian Lake. The widespread overburden of mine tailing and the annual drawdown of the reservoir of up to 9 metres has created a severely stressed environment for the fish community.

Although excessive levels of metal contamination were observed in Red Indian Lake bed sediments the levels of total metals in muscle tissue were very similar to levels found in salmonid fish species (38 samples) from three pristine Labrador headwater lakes (Lockerbie, 1987) as illustrated in Table 15. The range of values varied more in Labrador probably since many age classes were represented in the sample.

Two of the six Red Indian Lake fish slightly exceeded 0.5 mg/kg guideline for mercury set by National Health and Welfare Canada for fish intended for human consumption with levels of 0.55 and 0.62 mg/kg. Mercury may become a bioaccumulation hazard if environmental conditions are favorable for biomethylation resulting in the production of methyl mercury,

TABLE 15: COMPARISON OF HEAVY METAL CONCENTRATIONS IN FISH MUSCLE - WET WEIGHT) FROM RED INDIAN LAKE (1984) AND LABRADOR HEADWATER LAKES (1982, 1983, 1984) (1)

Heavy Metal	Red Indian Lake		Labrador Headwater Lakes	
	Median	Range	Median	Range
Cadmium	0.025	L0.02-0.05	L0.025	L0.025-0.07
Copper	0.43	0.32-0.47	0.37	L0.20 -0.83
Lead	0.12	0.07-0.15	L0.05	L0.05 -0.34
Zinc	9.0	6.0 -12.0	6.6	4.5 -57.0
Mercury	0.385	0.24-0.62	0.093	0.020-1.93

1 - Lockerbie, 1987.

the form of mercury found in most fish tissue (Callahan et. al., 1979). Mercury was strongly bioaccumulated in land-locked salmon in Sisson Reservoir (Bailey 1985) and salmonid species in Labrador headwater lakes where relatively low levels of mercury were found in bottom sediments (0.02 to 0.26 mg/kg) (Lockerbie, 1987). The relatively high levels of mercury in Red Indian Lake bottom sediments (0.24 to 1.00 mg/kg) appeared to be unavailable to the biota indicating that conditions were not favorable for any degree of biomethylation.

Bradley et. al. (1986) found that while metal content in sediment was a good indicator of the degree of lake contamination, it is not a satisfactory indicator of the

availability of metals to fish. Sediment levels in ten lakes near Sudbury, Ontario, ranged from 10.5 to 2900 mg/kg for copper and 130 to 545 mg/kg for zinc whereas copper values in muscle tissue only ranged from 0.6 to 1.2 mg/kg dry weight in seven species of fish. Zinc values ranged from 11.8 mg/kg in lake trout to 43.3 mg/kg in yellow perch. Values for copper and zinc varied very little from species to species or lake to lake regardless of metal loads in the sediment.

Although firm conclusions can not be reached from such a small sampling of Red Indian Lake fish, the lack of variation of extractable metals within the sample suggests these values may be representative of this older age grouping. Since the Red Indian Lake metal values in muscle tissue were similar to the pristine Labrador headwater lakes, we can suggest that the high metals in Red Indian Lake bed sediments are not available to fish. Additional sampling of Red Indian Lake fish would be required to confirm this conclusion.

In the Mira River fish, muscle tissue was analyzed from four individual longnose suckers and two pooled samples as well as two pooled white perch samples.

According to Table 14, the metal concentrations in longnose suckers though variable between parameters, are very similar to the same species from a St. Paul River headwater lake in Labrador (Lockerbie, 1987). The white perch collected at the

same site had higher mercury levels than the longnose sucker. The highest levels of mercury appear to occur in species which are fish-eaters such as the white perch, and levels gradually increase with the trophic level of the fish (Lockerbie, 1987).

In a study of mercury contaminated lakes in the Shubenacadie River Basin, it was found that although the muscle tissue of white suckers had elevated mercury levels, white perch had accumulated extremely high levels of mercury, ranging up to 2.0 mg/kg. (Eaton and Clair, 1985).

4. CONCLUSIONS

Although the environmental impact of the mining activities on the three basins studied may be considered fairly minor with respect to the present water quality and accumulation of metals by bottom sediments and biota, there were a few areas of concern.

Three of thirty-eight stations had elevated metal levels in the water column which may be detrimental to aquatic life and perhaps cause an avoidance reaction in the upstream migration of Atlantic Salmon. These stations were the South Tomogonops River at Hwy 430, Tomogonops River at mouth in New Brunswick and Buchans Brook in Newfoundland.

The present metals levels in water have improved greatly in the Tomogonops Northwest Miramichi River Basin as compared to the 1960's, however one concern associated with the mining activities are the zinc levels in the Northwest Miramichi River at Wayerton. Although the yearly average only slightly exceeds the water quality guidelne for zinc, the levels of 0.052 to 0.123 mg/L during spring break-up in 1984 fall into the range where harmful effects on fish and other aquatic organisms have been shown in laboratory studies. These high zinc levels probably contributed to the high body burdens of zinc in forage fish at this site.

Metal levels at all sites in the Exploits River Basin were at or below water quality guidelines, with the exception of Buchans Brook. The values for copper and zinc in 1984 were slightly higher than those determined by Morry and Cole in 1974.

Toxic metals such as arsenic, cadmium, copper and mercury were not detected in any water samples in the Salmon/Mira River Basin. Low levels of lead and zinc were detected in the cove immediately below the former discharge system, however they were not detected in the Salmon River below the cove.

A sediment/detritus sample collected on the South Tomogonops River at Hwy 430 though not representative of the basin provided an indication of the distribution of metals released from the mine's tailings area.

Excessive levels of metals were widely distributed in bottom sediments of Red Indian Lake as previously observed by Morry and Cole. Although the data collected during this survey indicate limited biomethylation processes are occurring, such a large reserve of metals may be a potential hazard by returning metals to the water column or transporting them to the Bay of Exploits during spring break-up.

High metal concentrations were found in sediments in the stagnant cove below the former effluent stream on the Salmon River, however with the exception of elevated levels in two

small ponds below the mine area, values in the Salmon River decreased below background 15 km downstream. In the Mira River, bottom sediments in the upper basin were slightly enriched with arsenic, lead and manganese.

The fish samples were inadequate both in volume of samples and variation of species to draw firm conclusions. The high zinc concentration of 81 mg/kg (wet-weight) found in lake chub collected from the Northwest Miramichi River at Wayerton was much higher than any reported in the literature reviewed.

The metal concentrations found in Red Indian Lake land-locked salmon were very similar to values found in salmonid species from pristine Labrador headwater lakes which indicate that the excessive metals present in the sediments were relatively unavailable to the fish.

In the Mira River, metal concentrations in muscle tissue of longnose suckers were not elevated and comparable to levels found in the same species in Labrador. Although mercury levels were higher in white perch, they were low in comparison with the same fish from mercury contaminated lakes in the Shubenacadie River Basin.

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APPENDICES

APPENDIX I - SAMPLING STATIONS

TOMOGONOPS/NORTHWEST MIRAMICHI RIVER BASIN

1	N.W. Miramichi River at Hwy 430 bridge 8 km above confluence of Tomogonops River	00NB01BQ0056
2	South Tomogonops River at Hwy 430	00NB01BQ0004
3	Tomogonops River at bridge 200 m. above confluence with N.W. Miramichi River	00NB01BQ0006
4	N.W. Miramichi River at Wayerton at Hwy 430 bridge	00NB01BQ0044

EXPLOITS RIVER BASIN

1	Buchans Brook at Hwy Bridge	00NF02YN0005
2	Red Indian Lake, 1 km E of Buchans Island	01NF02YN0020 51NF02YN0020
3	Red Indian Lake, 5 km SE of Buchans Brook near center	01NF02YN0021 51NF02YN0021
4	Red Indian Lake, 5 km WNW of Millertown Dam	01NF02YN0022 51NF02YN0022
5	Red Indian Lake, 1.8 km NW of Millertown Dam	01NF02YN0023 51NF02YN0023
6	Red Indian Lake, 4 km W of Millertown at center	01NF02YN0024 51NF02YN0024
7	Red Indian Lake, 1.5 km W of Millertown Dam (Fish Tissue)	90NF02YN0001
8	Exploits River, 0.6 km below Millertown Dam	00NF02YO0014
9	Exploits River, 100 m below Island, 3.5 km of upstream of Badger	00NF02YO0015
10	Exploits River, 0.5 km above confluence of Aspen Brook	00NF02YO0016
11	Exploits River at Grand Falls	00NF02YO0001
12	Exploits River at Bishops Falls, 0.5 km above TCH Bridge	00NF02YO0017
13	Bay of Exploits, 1.3 km SW of High Point (near center of headlands)	03NF02YO0002 53NF02YO0002

14	Bay of Exploits, midway between Wigwam and Little Peter Points, 0.5 km from shore	03NF02YO0003 53NF02YO0003

SALMON/MIRA RIVER BASIN

1	Salmon River 50 m. above Java Mines effluent discharge stream	00NS01FJ0022 50NS01FJ0022
2	Salmon River at Cove 20 m downstream from effluent discharge stream and 5 m from Right Bank	50NS01FJ0023
3	Salmon River at Center of Cove 40 m downstream from effluent discharge stream and 20 m from Right Bank	00NS01FJ0024 50NS01FJ0024
4	Salmon River just below cove 100 m downstream from effluent discharge Stream	00NS01FJ0026
5	Salmon River 500 m downstream of effluent discharge stream	00NS01FJ0025 50NS01FJ0025
6	Salmon River at Upper Pond 1.2 km below effluent stream near center	01NS01FJ0034 51NS01FJ0034
7	Salmon River at Lower Pond 1.7 km below effluent stream near center	01NS01FJ0035 51NS01FJ0035
8	Salmon River at Salmon River bridge	00NS01FJ0001 50NS01FJ0001
9	Mira River at Grand South Mira, 4.5 km above confluence of Salmon River at center	01NS01FJ0027 51NS01FJ0027
10	Mira River at Glen Currie, 2.3 km above confluence of Salmon River at center	01NS01FJ0028 51NS01FJ0028
11	Mira River 500 m. below confluence of Salmon River and 200 m. from Left Bank	01NS01FJ0029
12	Mira River at Two Rivers Wildlife Park, 2 km below confluence of Salmon River, 200 m. from Left Bank	01NS01FJ0030 51NS01FJ0030
13	Mira River at Two Rivers Wildlife Park 2 km below confluence of Salmon River at center	01NS01FJ0031 51NS01FJ0031

14	Mira River at Two Rivers Wildlife Park 2 km below confluence of Salmon River 200 m. from Right Bank	01NS01FJ0032 51NS01FJ0032
15	Mira River 3.5 km below confluence of Salmon River at center	01NS01FJ0033 51NS01FJ0033
16	Mira R. at Marion Bridge, 500 m. below Hwy 327 bridge at center	00NS01FJ0020 50NS01FJ0020
17	Mira River near Sangaree 600 m WSW of Spencers Island	02NS01FJ0002 52NS01FJ0002
18	Mira River at Mira River Provincial Park, 600 m. NE of Brickyard Point	02NS01FJ0004 52NS01FJ0004

APPENDIX II : MAJOR ION DATA - TOMOGONOPS/NORTHWEST MIRAMICHI RIVER BASIN

	STN	DATE	TIME	COLOR R.UNITS	CALCIUM MG/L	T.ALKAL MG/L	TURBIDITY MG/L	MAGNESIUM MG/L	POTASSIUM MG/L	SODIUM MG/L
1	00NB01BQ0056	19-JUN-84	1100	20	4.85	12.7	0.7	0.68	0.6	1.6
2	00NB01BQ0056	20-JUN-84	930	60	4.25	10.8	0.5	0.63	0.3	1.3
3	00NB01BQ0056	21-JUN-84	930	40	4.00	12.2	0.5	0.63	0.3	1.1
4	00NB01BQ0004	19-JUN-84	1125	10	208.00	9.6	2.2	5.10	2.2	13.9
5	00NB01BQ0004	19-JUN-84	1130	10	208.00	9.5	2.2	5.50	2.1	13.1
6	00NB01BQ0004	19-JUN-84	1120	10	206.00	9.7	2.2	5.70	2.2	14.1
7	00NB01BQ0004	20-JUN-84	945	10	240.00	12.5	1.4	5.00	2.4	14.8
8	00NB01BQ0004	21-JUN-84	1100	10	258.00	13.8	1.1	5.00	2.3	14.5
9	00NB01BQ0006	19-JUN-84	1212	40	26.00	9.2	1.5	1.35	0.5	2.2
10	00NB01BQ0006	20-JUN-84	1050	50	26.00	9.2	1.4	1.28	0.4	2.6
11	00NB01BQ0006	21-JUN-84	1005	40	29.50	9.2	1.5	1.40	0.5	2.6
12	00NB01BQ0006	21-JUN-84	1010	40	29.50	9.5	1.6	1.40	0.5	2.8
13	00NB01BQ0006	21-JUN-84	1000	40	30.00	9.5	1.5	1.40	0.5	2.5
14	00NB01BQ0044	19-JUN-84	1000	40	9.30	10.6	0.8	0.83	0.3	1.4
15	00NB01BQ0044	20-JUN-84	900	70	7.30	9.2	0.7	0.80	0.2	1.3
16	00NB01BQ0044	20-JUN-84	905	60	7.50	9.2	0.7	0.80	0.3	1.5
17	00NB01BQ0044	20-JUN-84	910	60	7.50	9.3	0.7	0.80	0.3	1.3
18	00NB01BQ0044	21-JUN-84	900	60	8.50	9.6	1.2	0.55	0.3	1.5

	PH PH UNITS	CHLORIDE MG/L	SULPHATE MG/L	SILICA MG/L	SPCOND US/CM	DOC MG/L	N-NO3 MG/L	N-TOTAL MG/L
1	6.5	0.7	3.0	5.7	36	4.6	L.01	0.08
2	6.6	0.6	3.5	6.4	32	9.7	0.04	0.11
3	6.6	0.7	3.2	5.8	35	7.8	0.01	0.08
4	6.4	12.6	530.0	3.4	1040	3.1	0.16	0.56
5	6.3	12.4	530.0	3.4	1040	3.5	0.16	0.55
6	6.2	12.5	530.0	3.4	1030	3.6	0.16	0.54
7	6.5	14.3	610.0	3.3	1150	3.1	0.17	0.66
8	6.5	16.0	610.0	3.2	1200	3.6	0.19	0.66
9	6.3	2.1	65.0	3.8	172	7.8	0.14	0.21
10	6.5	2.1	62.0	3.9	170	5.3	0.12	0.20
11	6.5	2.4	77.0	3.9	199	7.8	0.14	0.20
12	6.5	2.4	80.0	3.9	200	7.6	0.14	0.21
13	6.5	2.4	80.0	4.3	199	5.0	0.14	0.20
14	6.5	1.3	16.0	4.9	66	6.9	0.04	0.10
15	6.5	1.0	13.7	4.9	58	9.9	0.04	0.10
16	6.5	1.0	13.5	5.0	58	10.0	0.05	0.11
17	6.5	1.0	13.8	4.9	58	10.0	0.03	0.09
18	6.5	1.1	15.7	4.9	64	9.9	0.03	0.11

APPENDIX III : MAJOR ION DATA - EXPLOITS RIVER BASIN

	STN	SDATE	SAMPLE DEPTH	WATER DEPTH M	FIELD TEMP - C	COLOUR R. UNITS	CALCIUM MG/L	T.ALKAL MG/L	TURBIDITY JTU	MAGNESIUM MG/L
1	00NF02YN0005	26-JUL-84					3.8	4.4	0.6	0.48
2	00NF02YN0005	27-JUL-84				30	3.8	4.2	0.6	0.45
3	00NF02YN0005	29-JUL-84				30	5.2	5.1	0.7	0.59
4	01NF02YN0020	27-JUL-84	SURFACE	20			2.3	3.9	0.3	0.37
5	01NF02YN0020	27-JUL-84	BOTTOM	20			2.3	2.1	0.3	0.36
6	01NF02YN0021	27-JUL-84	SURFACE	37	15.5		2.3	3.7	0.3	0.36
7	01NF02YN0021	27-JUL-84	BOTTOM	37	8.5	30	2.3	3.6	0.4	0.37
8	01NF02YN0022	28-JUL-84	SURFACE	32	17.0		2.2	4.0	0.3	0.40
9	01NF02YN0022	28-JUL-84	BOTTOM	32	9.5		2.2	3.7	0.5	0.40
10	01NF02YN0023	28-JUL-84	SURFACE	41	18.0	25	2.2	4.0	0.3	0.40
11	01NF02YN0023	28-JUL-84	BOTTOM	41	10.5	30	2.2	3.5	0.7	0.40
12	01NF02YN0024	28-JUL-84	SURFACE	35	19.0		2.2	4.2	0.5	0.40
13	01NF02YN0024	28-JUL-84	BOTTOM	35	10.5		2.2	3.8	0.5	0.40
14	00NF02YD0014	26-JUL-84			17.0		2.4	4.0	0.4	0.36
15	00NF02YD0014	27-JUL-84			18.0	25	2.4	3.9	0.3	0.35
16	00NF02YD0015	29-JUL-84					2.4	4.1	0.3	0.40
17	00NF02YD0015	30-JUL-84				25	2.4	4.1	0.4	0.40
18	00NF02YD0015	31-JUL-84				25	2.4	4.3	0.3	0.41
19	00NF02YD0016	29-JUL-84					2.4	4.1	0.3	0.41
20	00NF02YD0016	30-JUL-84				25	2.4	4.2	0.3	0.40
21	00NF02YD0016	31-JUL-84				25	2.4	4.4	0.3	0.41
22	00NF02YD0001	30-JUL-84					2.5	4.7	0.4	0.42
23	00NF02YD0001	31-JUL-84				25	2.5	4.6	0.6	0.41
24	00NF02YD0017	29-JUL-84					2.6	4.7	0.6	0.45
25	00NF02YD0017	30-JUL-84				25	2.6	4.8	0.7	0.46
26	00NF02YD0017	31-JUL-84				25	2.6	4.9	0.9	0.45
27	03NF02YD0002	31-JUL-84		4			144.0	40.2	0.4	220.00
28	03NF02YD0003	31-JUL-84	SURFACE	4			196.0	54.8	0.3	600.00
29	03NF02YD0003	31-JUL-84	BOTTOPM	4	L5.		344.0	94.5	0.3	1040.00

APPENDIX III(CONT) : MAJOR ION DATA - EXPLOITS RIVER BASIN

	POTASSIUM MG/L	SODIUM MG/L	PH PH UNITS	CHLORIDE MG/L	SULPHATE MG/L	SILICA MG/L	SPCOND USIE/CM	DOC MG/L	N-NO3 MG/LX	N-TOTAL MG/L
1	0.10	1.6	6.7	1.7	6.8	3.0	34	4.4	L.01	0.09
2	0.10	1.5	6.7	1.6	6.5	2.9	34	3.9	L.01	0.10
3	0.15	1.7	6.7	2.0	10.0	3.3	45	4.6	L.01	0.10
4	0.10	1.3	6.7	1.5	2.8	2.3	22	4.7	L.01	0.09
5	0.10	1.3	6.3	1.6	2.8	2.3	23	4.6	0.50	0.57
6	0.10	1.3	6.7	1.5	2.8	2.3	23	4.6	0.03	0.10
7	0.10	1.4	6.7	1.5	2.8	2.4	22	4.9	0.02	0.12
8	0.10	1.3	6.8	1.4	2.8	2.3	22	3.9	0.02	0.09
9	0.10	1.4	6.6	1.5	2.9	2.4	22	5.0	0.04	0.11
10	0.10	1.4	6.8	1.5	2.8	2.3	22	10.0	0.01	0.09
11	0.10	1.3	6.6	1.6	2.9	2.4	22	5.2	0.06	0.13
12	0.15	1.3	6.8	1.5	2.5	2.2	23	4.6	0.04	0.11
13	0.15	1.4	6.6	1.6	2.9	2.4	23	4.6	0.02	0.11
14	0.10	1.4	6.8	1.5	2.5	2.2	22	4.5	L.01	0.10
15	0.10	1.3	6.7	1.4	2.5	2.2	22	4.4	L.01	0.07
16	0.10	1.5	6.8	1.6	2.4	2.1	23	4.4	0.05	0.10
17	0.10	1.4	6.8	1.6	2.4	2.1	23	4.5	0.05	0.13
18	0.10	1.4	6.8	1.6	2.4	2.0	23	4.6	0.05	0.07
19	0.10	1.4	6.8	1.5	2.5	2.0	23	4.6	0.04	0.07
20	0.10	1.5	6.8	1.6	2.5	2.0	23	4.8	L.01	0.07
21	0.10	1.3	6.8	1.6	2.4	2.0	23	4.6	0.05	0.11
22	0.10	1.6	6.7	1.6	2.9	1.9	25	4.2	L.01	0.08
23	0.10	1.6	6.7	1.6	3.1	2.0	25	4.6	L.01	0.06
24	0.10	1.9	6.7	1.6	3.5	1.9	27	5.1	L.01	0.07
25	0.10	1.7	6.7	1.6	3.5	1.9	27	5.1	L.01	0.07
26	0.10	1.7	6.7	1.5	3.2	1.9	26	4.9	L.01	0.08
27	155.00	4100.0	7.5	6800.0	990.0	1.0	19800	16.0	L.01	0.11
28	220.00	5500.0	7.6	9300.0	1300.0	0.9	26200		L.01	L.10
29	390.00	10300.0	7.8	16900.0	2620.0	0.3	44400		0.01	0.10

APPENDIX IV : MAJOR ION DATA - SALMON/MIRA RIVER BASIN

	STN	DATE	TIME	COLOR R.UNITS	CALCIUM MG/L	T.ALKAL MG/L	TURBIDITY MG/L	MAGNESIUM MG/L	POTASSIUM MG/L	SODIUM MG/L
1	00NS01FJ0022	05-NOV-85	1000	20	7.2	6.4	0.8	1.4	0.48	6.5
2	00NS01FJ0024	05-NOV-85	1030	5	7.7	17.4	0.8	1.5	0.50	5.3
3	00NS01FJ0026	05-NOV-85	1050	20	7.4	7.0	1.5	1.4	0.48	6.5
4	00NS01FJ0025	05-NOV-85	1100	20	7.5	6.7	0.7	1.4	0.48	6.7
5	01NS01FJ0034	05-NOV-85	1300	25	6.4	5.6	0.9	1.3	0.48	5.9
6	01NS01FJ0035	05-NOV-85	1210	35	5.9	5.0	1.0	1.3	0.53	5.6
7	00NS01FJ0001	05-NOV-85	1400	30	4.1	4.1	1.1	1.1	0.50	4.6
8	01NS01FJ0027	25-SEP-85	1500	5	6.1	3.6	0.3	13.0	5.0	106
9	01NS01FJ0028	25-SEP-85	1630	5	6.5	3.6	0.4	14.0	4.5	105
10	01NS01FJ0029	25-SEP-85	1100	5	6.6	3.8	0.3	15.0	5.7	123
11	01NS01FJ0030	26-SEP-85	1400	5	6.8	4.5	0.4	16.0	5.0	127
12	01NS01FJ0031	24-SEP-85	1630	5	6.8	4.8	0.4	16.2	5.5	126
13	01NS01FJ0032	26-SEP-85	1600	5	6.6	3.8	0.3	15.0	5.0	128
14	01NS01FJ0033	25-SEP-85	1300	5	7.1	4.0	0.3	16.0	5.5	135
15	00NS01FJ0020	26-SEP-85	1000	L5.	98.0	28.9	0.4	302.0	100.0	2900
16	02NS01FJ0002	26-SEP-85	1150	L5.	182.0	49.8	0.4	556.0	196.0	5100
17	02NS01FJ0004	24-SEP-85	1400	L5.	221.0	62.3	0.2	643.0	250.0	6200

	PH PH UNITS	CHLORIDE MG/L	SULPHATE MG/L	SILICA MG/L	SPCOND MG/L	DOC MG/L	N-NO3 MG/L	N-TOTAL MG/L
1	6.7	11.3	14.4	2.6	88	6.4	0.01	L.1
2	6.9	7.9	7.7	6.4	82	2.7	0.03	L.1
3	6.8	11.4	14.0	2.7	89	6.2	0.01	L.1
4	6.6	11.2	14.1	2.7	90	6.2	0.01	L.1
5	6.6	10.2	12.6	2.8	81	7.2	0.01	L.1
6	6.6	9.5	11.1	2.7	75	8.0	0.02	0.10
7	6.4	8.2	7.1	2.8	59	6.4	0.05	0.12
8	6.7	200	30	0.8	727	4.2	0.05	L.1
9	6.7	220	31	0.8	784	4.2	0.04	L.1
10	6.7	230	31	0.8	826	4.3	0.05	L.1
11	6.8	230	37	0.8	842	4.2	0.05	L.1
12	6.8	240	35	0.8	849	4.2	0.05	L.1
13	6.7	230	33	0.8	841	4.3	0.04	L.1
14	6.7	260	33	0.8	909	4.7	0.04	L.1
15	7.5	4900	650	0.4	14100		0.01	L.1
16	7.8	9000	1250	0.2	24500		L.01	L.1
17	8.0	11200	1570	0.1	29600		L.01	L.1

APPENDIX V : METALS IN WATER (MG/L) IN TOMOGONOPS/NORTHWEST MIRAMICHI RIVER BASIN

STATION	DATE	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM
NW MIRAMICHI AT HWY 430	JUNE 19	0.003	0.003	L0.01	L0.001	0.010	0.02	0.07
		0.004	L0.002	L0.01	L0.001	0.100	0.02	0.07
		0.005	L0.002	L0.01	L0.001	0.100	0.02	0.07
	JUNE 20	0.002	L0.002	0.01	L0.001	0.140	0.01	0.08
		0.002	L0.002	0.01	L0.001	0.140	0.02	0.11
		0.002	L0.002	0.01	L0.001	0.120	0.01	0.08
	JUNE 21	L0.002	L0.002	L0.01	L0.001	0.100	0.01	0.06
		L0.002	L0.002	L0.01	L0.001	0.130	0.01	0.07
		L0.002	L0.002	L0.01	L0.001	0.110	0.01	0.06
SOUTH TOMOGONOPS RIVER	JUNE 19	0.100	0.200	0.31	L0.001	0.200	0.68	0.19
		0.100	0.210	0.31	L0.001	0.200	0.69	0.20
		0.100	0.200	0.31	L0.001	0.200	0.69	0.20
	JUNE 20	0.100	0.008	0.22	0.001	0.120	0.53	0.13
		0.100	0.010	0.22	L0.001	0.123	0.53	0.13
		0.100	0.009	0.22	L0.001	0.130	0.54	0.14
	JUNE 21	0.090	0.010	0.19	L0.001	0.130	0.48	0.11
		0.090	0.010	0.19	L0.001	0.130	0.47	0.13
		0.100	0.010	0.19	L0.001	0.130	0.47	0.13
TOMOGONOPS R AT MOUTH	JUNE 19	0.020	0.003	0.26	L0.001	0.270	0.31	0.28
		0.020	0.005	0.26	L0.001	0.270	0.30	0.23
		0.030	0.004	0.26	L0.001	0.330	0.30	0.22
	JUNE 20	0.030	0.003	0.25	L0.001	0.220	0.32	0.19
		0.030	0.003	0.25	L0.001	0.220	0.32	0.18
		0.020	0.003	0.25	L0.001	0.210	0.32	0.18
	JUNE 21	0.030	0.002	0.31	L0.001	0.200	0.44	0.23
		0.030	0.002	0.31	L0.001	0.200	0.44	0.23
		0.012	0.003	0.31	L0.001	0.200	0.44	0.23
NW MIRAMICHI AT WAVERTON	JUNE 19	0.003	L0.002	0.04	L0.001	0.200	0.07	0.08
		0.005	L0.002	0.04	L0.001	0.200	0.07	0.07
		0.004	L0.002	0.04	L0.001	0.200	0.07	0.07
	JUNE 20	0.003	L0.002	0.05	L0.001	0.200	0.08	0.13
		0.005	0.002	0.05	L0.001	0.210	0.07	0.11
		0.003	0.002	0.05	L0.001	0.210	0.08	0.11
	JUNE 21	0.006	0.002	0.06	L0.001	0.200	0.08	0.16
		0.003	L0.002	0.06	L0.001	0.210	0.08	0.15
		0.003	0.002	0.06	L0.001	0.210	0.08	0.14

APPENDIX VI : EXTRACTABLE METALS IN WATER (MG/L) - EXPLOITS RIVER BASIN

STATION	DATE	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM
1	JULY 26	0.011	0.045	0.28	L0.001	0.35	0.04	0.13
		0.011	0.029	0.28	L0.001	0.31	0.04	0.13
		0.010	0.021	0.27	L0.001	0.25	0.03	0.10
	JULY 27	0.009	0.020	0.26	L0.001	0.25	0.03	0.09
		0.009	0.019	0.25	L0.001	0.25	0.03	0.09
		0.009	0.020	0.26	L0.001	0.24	0.03	0.09
	JULY 29	0.012	0.016	0.44	L0.001	0.23	0.04	0.08
		0.012	0.015	0.44	L0.001	0.22	0.04	0.08
		0.012	0.016	0.44	L0.001	0.22	0.04	0.09
2	JULY 28	0.003	0.004	0.04	L0.001	0.043	L0.01	0.06
	(SURFACE)	0.003	0.004	0.04	L0.001	0.027	L0.01	0.07
		0.003	0.004	0.04	L0.001	0.051	L0.01	0.07
	(BOTTOM)	0.004	0.002	0.04	L0.001	0.035	L0.01	0.05
		0.006	0.002	0.04	L0.001	0.044	L0.01	0.06
		0.005	0.005	0.03	L0.001	0.030	L0.01	0.06
3	JULY 27	0.004	0.005	0.05	L0.001	L0.05	L0.01	0.06
	(SURFACE)	0.003	0.005	0.04	L0.001	L0.05	L0.01	0.05
	(BOTTOM)	0.004	0.005	0.04	L0.001	0.07	L0.01	0.09
		0.003	0.005	0.04	L0.001	0.07	L0.01	0.07
		0.006	0.007	0.06	L0.001	0.08	L0.01	0.07
4	JULY 28	0.003	0.003	0.04	L0.001	0.05	L0.01	0.05
	(SURFACE)	0.003	0.002	0.04	L0.001	L0.05	L0.01	0.05
		0.003	0.002	0.04	L0.001	L0.05	L0.01	0.04
	(BOTTOM)	0.004	0.006	0.04	L0.001	0.11	L0.01	0.08
		0.004	0.005	0.04	L0.001	0.09	L0.01	0.07
		0.005	0.006	0.04	L0.001	0.09	L0.01	0.07

1 BUCHANS BROOK AT HWY BRIDGE
2 RED INDIAN LAKE, 1KM E. OF BUCHANS ISLAND
3 RED INDIAN LAKE, 5KM SE OF BUCHANS BROOK AT CENTER
4 RED INDIAN LAKE, 5KM NW OF EXPLOITS RIVER DAM

APPENDIX VI (CONT) : EXTRACTABLE METALS IN WATER (MG/L) - EXPLOITS RIVER BASIN

STATION	DATE	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM
5	JULY 28	0.002	L0.002	0.04	L0.001	0.05	L0.01	0.05
	(SURFACE)	0.003	0.002	0.04	L0.001	0.05	L0.01	0.05
		0.003	0.003	0.04	L0.001	0.05	L0.01	0.05
	(BOTTOM)	0.003	0.004	0.04	L0.001	0.11	0.01	0.08
		0.004	0.008	0.04	L0.001	0.15	0.02	0.08
		0.004	0.006	0.07	L0.001	0.11	0.01	0.07
6	JULY 28	0.004	0.002	0.04	L0.001	0.11	0.01	0.07
	(SURFACE)	0.003	0.008	0.04	L0.001	0.08	0.01	0.08
		0.003	0.005	0.03	L0.001	0.06	0.01	0.06
	(BOTTOM)	0.003	0.010	0.04	L0.001	0.19	0.05	0.09
		0.003	0.008	0.04	L0.001	0.12	0.05	0.08
		0.007	0.005	0.04	L0.001	0.10	0.03	0.08
8	JULY 26	L0.002	0.003	0.04	0.002	0.030	L0.01	0.05
		0.002	0.003	0.03	0.002	0.035	0.01	0.06
		0.003	0.003	0.03	0.002	0.037	0.01	0.06
	JULY 27	0.002	0.003	0.04	0.002	0.035	L0.01	0.06
		0.003	0.002	0.04	0.002	0.034	0.01	0.06
		0.003	0.002	0.04	0.002	0.028	0.01	0.06
	JULY 29	0.003	0.002	0.04	0.002	0.040	0.01	0.06
		0.003	0.003	0.03	L0.001	0.042	0.01	0.06
		0.003	0.002	0.03	L0.001	0.044	0.01	0.07
9	JULY 29	0.003	L0.002	0.03	L0.001	0.05	0.01	0.05
		0.003	L0.002	0.03	L0.001	0.05	0.01	0.05
		0.003	L0.002	0.03	L0.001	0.05	0.01	0.05
	JULY 30	0.003	0.002	0.03	L0.001	0.05	0.01	0.06
		0.002	0.002	0.03	L0.001	0.05	0.01	0.05
		0.003	0.002	0.03	L0.001	L0.05	0.01	0.06
	JULY 31	0.003	0.002	0.03	L0.001	0.05	0.02	0.05
		0.003	0.003	0.03	L0.001	0.05	0.02	0.05
		0.003	0.002	0.03	L0.001	0.05	0.02	0.04

5 RED INDIAN LAKE, 1.8KM NW OF EXPLOITS RIVER DAM
6 RED INDIAN LAKE, 4KM W. OF MILLERTOWN AT CENTER
8 EXPLOITS RIVER, 0.6 KM BELOW MILLERTOWN DAM
9 EXPLOITS RIVER, 100M BELOW ISLAND, 3.5KM UPSTREAM OF BRIDGE

APPENDIX VI (CONT) : EXTRACTABLE METALS IN WATER (MG/L) - EXPLOITS RIVER BASIN

STATION	DATE	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM
10	JULY 29	0.002	L0.002	0.02	L0.001	0.05	0.01	0.05
		0.002	L0.002	0.02	L0.001	0.05	0.01	0.05
		0.002	L0.002	0.02	L0.001	0.05	0.01	0.05
	JULY 30	0.002	0.002	0.03	L0.001	0.06	0.01	0.05
		0.002	0.002	0.03	L0.001	0.05	0.01	0.05
		0.002	L0.002	0.03	L0.001	0.05	0.01	0.05
	JULY 31	0.002	L0.002	0.03	L0.001	0.008	0.01	0.06
11	JULY 30	0.002	L0.002	0.03	L0.001	0.10	0.02	0.06
		0.002	L0.002	0.03	L0.001	0.08	0.02	0.06
		0.002	L0.002	0.03	L0.001	0.08	0.02	0.06
	JULY 31	0.002	L0.002	0.03	L0.001	0.08	0.02	0.06
		0.003	L0.002	0.03	L0.001	0.08	0.02	0.06
		0.003	0.002	0.02	L0.001	0.05	0.02	0.06
12	JULY 29	0.002	L0.002	0.02	L0.001	0.08	0.03	0.05
		0.002	L0.002	0.02	L0.001	0.08	0.03	0.05
		0.002	L0.002	0.02	L0.001	0.08	0.03	0.05
	JULY 30	0.003	L0.002	0.02	L0.001	0.08	0.03	0.05
		0.002	L0.002	0.02	L0.001	0.08	0.03	0.06
		0.002	L0.002	0.02	L0.001	0.09	0.03	0.06
	JULY 31	0.002	L0.002	0.02	L0.001	0.10	0.02	0.06
		0.003	L0.002	0.02	L0.001	0.10	0.02	0.06
		0.003	L0.002	0.02	L0.001	0.10	0.02	0.06
13	JULY 31	0.003	0.002	0.03	L0.001	0.12	0.04	L0.010
		0.003	L0.002	0.03	L0.001	0.12	0.04	L0.010
		0.03	L0.002	0.03	L0.001	0.12	0.04	L0.010
14	JULY 31	0.003	L0.002	0.02	L0.001	0.14	0.05	L0.010
	(SURFACE)	0.003	L0.002	0.02	L0.001	0.14	0.05	L0.010
		0.003	L0.002	0.02	L0.001	0.14	0.05	L0.010
	(BOTTOM)	0.002	L0.002	0.02	L0.001	0.28	0.08	L0.010
		0.003	0.002	0.02	L0.001	0.29	0.08	L0.010
		0.003	0.002	0.02	L0.001	0.28	0.08	L0.010

10 EXPLOITS RIVER, 0.5KM ABOVE CONFLUENCE OF ASPEN BROOK
11 EXPLOITS RIVER AT GRAND FALLS
12 EXPLOITS RIVER AT BISHOPS FALLS, 0.5KM ABOVE TCH BRIDGE
13 BAY OF EXPLOITS, 1.3KM SW OF HIGH POINT
14 BAY OF EXPLOITS, MIDWAY BETWEEN WIGWAM AND LITTLE PETER POINTS

APPENDIX VII : EXTRACTABLE METALS IN WATER (MG/L) - SALMON/MIRA RIVER BASIN

STATION	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM	ARSENIC	MERCURY
1	L0.002	L0.002	L0.01	L0.001	0.25	0.06	0.097	L0.0002	L0.02
	L0.002	L0.002	L0.01	L0.001	0.20	0.04	0.073	-	-
	L0.002	L0.002	L0.01	L0.001	0.21	0.05	0.073	-	-
3	L0.002	0.006	0.024	L0.001	0.13	0.21	0.053	L0.0002	L0.02
	L0.002	0.007	0.028	L0.001	0.14	0.27	0.051	-	-
	L0.002	0.007	0.024	L0.001	0.15	0.23	0.051	-	-
4	L0.002	0.006	L0.01	L0.001	0.2	0.03	0.068	L0.0002	L0.02
	L0.002	0.003	L0.01	L0.001	0.2	0.03	0.072	-	-
	L0.002	L0.002	L0.01	L0.001	0.19	0.03	0.072	-	-
5	L0.002	L0.002	L0.01	L0.001	0.2	0.04	0.075	L0.0002	L0.02
6	L0.002	L0.002	L0.01	L0.001	0.21	0.04	0.097	L0.0002	L0.02
7	L0.002	L0.002	L0.01	L0.001	0.23	0.05	0.12	L0.0002	L0.02
8	L0.002	L0.002	L0.01	L0.001	0.23	0.06	0.097	L0.0002	L0.02

1 SALMON RIVER 50 M ABOVE JAVA MINE
3 SALMON RIVER 40 M DOWNSTREAM OF EFFLUENT STREAM
4 SALMON RIVER 100 M DOWNSTREAM OF EFFLUENT STREAM
5 SALMON RIVER 500 M DOWNSTREAM OF EFFLUENT STREAM
6 SALMON RIVER AT UPPER POND
7 SALMON RIVER AT LOWER POND
8 SALMON RIVER AT SALMON RIVER ROAD

APPENDIX VII(CONT) : EXTRACTABLE METALS IN WATER (MG/L) - SALMON/MIRA RIVER BASIN

STATION	COPPER	LEAD	ZINC	CADMIUM	IRON	MANGANESE	ALUMINUM	ARSENIC	MERCURY (UG/L)
9	L0.002	L0.002	L0.01	L0.001	0.06	0.03	0.041	-	L0.02
	L0.002	L0.002	0.02	L0.001	0.06	0.03	0.041	-	-
	L0.002	L0.002	0.02	L0.001	0.06	0.03	0.040	-	-
10	L0.002	L0.002	L0.01	L0.001	0.053	0.03	0.049	-	L0.02
11	L0.002	L0.002	L0.01	L0.001	0.05	0.03	0.043	-	L0.02
	L0.002	L0.002	L0.01	L0.001	0.06	0.03	0.043	-	L0.02
	L0.002	L0.002	L0.01	L0.001	0.07	0.03	0.043	-	L0.02
12	L0.002	L0.002	L0.01	L0.001	0.06	0.03	0.044	-	L0.02
	L0.002	L0.002	L0.01	L0.001	0.06	0.03	0.047	-	L0.02
	L0.002	L0.002	L0.01	L0.001	0.06	0.03	0.042	-	L0.02
13	L0.002	L0.002	L0.01	L0.001	0.052	0.03	0.035	-	L0.02
14	L0.002	L0.002	L0.01	L0.001	0.077	0.04	0.04	L0.0002	L0.02
15	L0.002	L0.002	L0.01	L0.001	0.051	0.03	0.045	-	L0.02
16	L0.002	L0.002	L0.01	L0.001	0.052	0.03	0.015	L0.0002	L0.02
17	L0.002	L0.002	0.012	L0.001	0.11	0.03	L0.01	L0.0002	L0.02
18	L0.002	L0.002	0.014	L0.001	0.15	0.03	L0.01	-	-

9 MIRA RIVER AT GRAND SOUTH MIRA
10 MIRA RIVER ATN GLEN CURRIE
11 MIRA RIVER 500M BELOW CONFLUENCE OF SALMON RIVER
12 MIRA RIVER 2 KM BELOW CONFLUENCE OF SALMON RIVER (LEFT BANK)
13 MIRA RIVER 2 KM BELOW CONFLUENCE OF SALMON RIVER (CENTRE)
14 MIRA RIVER 2 KM BELOW CONFLUENCE OF SALMON RIVER (RIGHT BANK)
15 MIRA RIVER 3.5 KM BELOW CONFLUENCE OF SALMON RIVER
16 MIRA RIVER AT MARION BRIDGE
17 MIRA RIVER NEAR SANGAREE
18 MIRA RIVER AT PROVINCIAL PARK

APPENDIX VIII : COPPER AND ZINC IN WATER(MG/L) AT
NORTHWEST MIRAMICHI AT WAYERTON,1984
(HEATH STEELE MINES DATA)

	DATE	FLOW CMS	COPPER	ZINC
1	04-JAN-84	9.60	0.004	0.0510
2	11-JAN-84	8.00	0.007	0.0460
3	18-JAN-84	6.80	0.005	0.0300
4	25-JAN-84	5.80	0.003	0.0370
5	02-FEB-84	5.35	0.005	0.0260
6	08-FEB-84	7.80	0.011	0.0400
7	15-FEB-84	8.00	0.005	0.0340
8	22-FEB-84	8.60	0.003	0.0470
9	28-FEB-84	10.40	0.002	0.0440
10	07-MAR-84	7.60	0.002	0.0300
11	14-MAR-84	7.20	0.002	0.0250
12	21-MAR-84	7.00	0.007	0.0390
13	28-MAR-84	7.00	0.005	0.0440
14	04-APR-84	11.30	0.005	0.0390
15	11-APR-84	7.60	0.009	0.0650
16	18-APR-84	10.50	0.021	0.0830
17	25-APR-84	15.00	0.008	0.1230
18	02-MAY-84	132.00	0.006	0.0790
19	16-MAY-84	104.00	0.004	0.0710
20	24-MAY-84	44.60	0.005	0.0740
21	30-MAY-84	55.00	0.005	0.0680
22	05-JUN-84	74.00	0.004	0.0580
23	13-JUN-84	30.00	0.004	0.0520
24	19-JUN-84	31.00	0.006	0.0520
25	26-JUN-84	24.00	0.003	0.0410
26	03-JUL-84	16.80	0.005	0.0360
27	11-JUL-84	19.20	0.002	0.0280
28	17-JUL-84	11.20	0.003	0.0250
29	25-JUL-84	8.20	0.002	0.0270
30	31-JUL-84	7.90	0.004	0.0200
31	08-AUG-84	9.40	0.002	0.0140
32	15-AUG-84	8.20	0.002	0.0110
33	21-AUG-84	6.80	0.002	0.0210
34	29-AUG-84	5.80	0.002	0.0170
35	06-SEP-84	5.80	0.002	0.0190
36	12-SEP-84	3.90	0.002	0.0150
37	19-SEP-84	2.80	0.002	0.0121
38	26-SEP-84	3.00	0.002	0.0210
39	03-OCT-84	3.40	0.002	0.0270
40	10-OCT-84	3.80	0.002	0.0210
41	17-OCT-84	3.00	0.003	0.0260
42	24-OCT-84	2.80	0.002	0.0210
43	31-OCT-84	2.80	0.002	0.0270
44	07-NOV-84	2.40	0.002	0.0230
45	13-NOV-84	1.80	0.002	0.0170
46	19-NOV-84	3.60	0.004	0.0280
47	27-NOV-84	3.40	0.001	0.0350
48	03-DEC-84	3.80	0.003	
49	11-DEC-84	4.00	0.002	0.0430
50	17-DEC-84	3.60	0.002	0.0420

APPENDIX IX : COPPER, LEAD AND ZINC IN WATER (MG/L) - EXPLOITS RIVER AT GRAND FALLS
(IHD AND WQB OVERVIEW MONITORING DATA)

DATE	TURBIDITY	COPPER	LEAD	ZINC	DATE	TURBIDITY	COPPER	LEAD	ZINC
03-MAY-67	7.0	0.020		0.200	21-JAN-80	1.3		0.005	0.039
03-OCT-67	1.0	L0.010		0.180	11-MAR-80	0.9		0.007	0.028
03-JAN-68	0.7	L0.010		0.110	07-MAY-80	0.6		0.003	0.008
03-APR-68	2.1	0.020		0.100	23-JUN-80	0.4	0.002	0.002	0.019
19-APR-68	2.0			0.140	13-AUG-80	1.0	0.003	0.002	0.028
17-JUN-68	0.2	0.070		0.090	22-SEP-80	0.6	0.002	0.004	0.036
03-JUL-68	0.4	0.010		0.130	18-OCT-80	0.5	0.002	0.003	0.025
28-AUG-68	1.2	0.020		0.160	12-NOV-80	0.7	0.002	0.002	0.019
03-OCT-68	1.3	0.010		0.130	04-DEC-80	0.4	0.002	0.002	0.022
28-NOV-68	2.0			0.050	10-FEB-81	0.4	0.003	0.005	0.031
03-JAN-69	0.3			0.140	10-MAR-81	0.5	0.002	0.004	0.023
03-MAR-69	1.5	0.050		0.100	09-APR-81	0.5	0.002	0.002	0.012
03-APR-69	0.5	0.050		0.070	08-JUN-81	0.6	0.002	0.002	0.019
07-MAY-69	0.8	0.020		0.090	14-JUL-81	1.3	0.002	0.002	0.030
03-JUL-69	0.8	0.020		0.040	12-AUG-81	0.7	0.003	0.002	0.030
03-SEP-69	0.5	0.080		0.100	16-SEP-81	0.7	0.003	0.004	0.020
04-NOV-69	2.3	0.060		0.100	23-OCT-81	0.6	0.003	0.003	0.019
05-JAN-70	0.6	0.050		0.100	18-NOV-81	1.8	0.003	0.005	0.030
03-APR-70	0.7	L0.010		0.100	21-DEC-81	0.9	0.003	0.005	0.030
06-AUG-70	0.4	0.020		0.070	13-JAN-82	0.7	0.003	0.009	0.040
03-NOV-70	0.8	0.017		0.080	18-FEB-82	0.7	0.004	0.004	0.030
03-DEC-70	1.3	0.020		0.100	18-MAR-82		0.003	0.003	0.030
04-JAN-71	0.6	0.014	0.040	0.100	20-APR-82	1.2	0.002	0.012	0.030
04-APR-71	1.7	0.160	0.015	0.070	05-MAY-82	0.6	0.002	0.003	
05-JUL-71	0.3	0.018	0.004	0.060	24-JUN-82	1.0	0.002	0.003	0.030
04-OCT-71	0.1	0.010	0.002	0.080	17-AUG-82	0.6	0.002	0.002	0.020
03-JAN-72	0.8	0.007	0.007	0.070	09-SEP-82	0.4	0.003	0.002	0.030
03-APR-72	0.7	L0.001	0.007	0.037	14-OCT-82	0.6	0.002	0.003	0.030
03-JUL-72	0.3	0.005	0.005	0.044	04-NOV-82	0.9	0.002	0.003	0.030
03-OCT-72	0.6	0.003	0.005	0.100	14-DEC-82	0.9	0.002	0.006	0.030
05-DEC-72	0.7	L0.001	0.004	0.047	13-JAN-83	1.2	0.003	0.007	0.020
06-MAR-73	0.4	0.005	0.007	0.050	15-FEB-83	1.4	0.003	0.007	0.030
14-MAY-73	0.5	L0.001	0.013	0.032	22-MAR-83	0.7	0.002	0.004	0.020
05-JUL-73	0.1	L0.001	0.003	0.032	27-APR-83	0.7	0.002	0.002	0.030
15-OCT-73	0.1	0.003	0.004	0.049	18-MAY-83	1.0	0.004	0.002	0.020
03-JAN-74	0.8	0.002	0.010	0.050	08-JUN-83	1.0	0.002	0.006	0.020
08-APR-74	0.7	0.005	0.010	0.040	17-AUG-83	0.7	0.002	0.002	0.020
14-AUG-76	0.3	L0.002	0.003	0.030	21-SEP-83	1.1	0.003	0.002	0.030
14-AUG-76		L0.002	L0.002	0.030	28-OCT-83	0.6	0.006	0.002	0.060
03-JAN-77	0.3	0.030	0.004	0.080	25-NOV-83	0.7	0.003	0.002	0.030
04-APR-77	1.5	0.002	0.014	0.040	16-DEC-83	1.7	0.002	0.002	0.030
04-JUL-77	0.5	0.007	L0.002	0.026	18-JAN-84	0.7	0.004	0.004	0.030
03-OCT-77	0.6	0.006	0.003	0.028	14-FEB-84	1.1	0.002	0.002	0.010
06-JAN-78	0.7	0.004	L0.002	0.016	19-MAR-84	0.5	0.003	0.002	0.020
03-APR-78	1.2	0.008	0.003	0.028	10-MAY-84	0.5	0.002	0.003	0.014
06-JUL-78	1.0	0.002	L0.002	L0.021	10-MAY-84	0.6	0.002	0.003	0.012
03-OCT-78	0.7	L0.002	L0.002	0.029	10-MAY-84	0.4	0.002	0.002	0.015
20-MAR-79	2.5		0.009	0.011	21-JUN-84	0.4	0.002	0.002	0.010
10-MAY-79	1.3		L0.002	L0.002	01-AUG-84	0.6	0.002	0.002	0.020
17-JUL-79	1.7		0.005	0.027	06-SEP-84	0.6	0.002	0.002	0.010
10-SEP-79	2.2		0.003	0.025	25-OCT-84	0.6	0.002	0.002	0.030
15-NOV-79	0.9		0.006	0.028	11-DEC-84	0.7	0.002	0.002	0.030

APPENDIX X : HEAVY METALS IN WATER (MG/L) AT SALMON RIVER AT SALMON RIVER ROAD (IHD AND WQB OVERVIEW MONITORING DATA)

DATE	TIME	COPPER	LEAD	ZINC	CADMIUM
20-AUG-71	1300	0.007	L0.001	0.009	L0.001
13-NOV-71	1300	0.012		0.013	
13-FEB-72	1200	L0.001	0.005	0.004	L0.001
02-MAY-72	1200	L0.001	0.002	0.002	L0.001
30-JUL-72	1200	0.005	0.002	0.005	L0.001
17-JAN-73	1200	L0.001	L0.001	0.016	L0.001
03-APR-73	1200	L0.001	0.004	0.004	L0.001
11-JUN-73	1200	L0.001	0.004	L0.001	L0.001
09-SEP-73	1200	L0.001	L0.001	0.002	L0.001
07-FEB-74	1140	0.008	0.006	0.002	L0.001
29-SEP-80	755	L0.002	0.002	0.006	L0.001
21-OCT-80	1201		0.002		
19-NOV-80	1011	L0.002	L0.002	0.005	L0.001
20-JAN-81	1220	L0.002	L0.002	0.005	L0.001
10-MAR-81	1030	L0.002	0.004	0.002	L0.001
12-MAY-81	1100	L0.002		0.002	L0.001
15-JUL-81	1425	L0.002	0.005	0.005	L0.001
08-SEP-81	1520	L0.002	0.003	L0.002	L0.001
16-NOV-81	1520	0.002	L0.002	0.007	L0.001
12-JAN-82	1201	L0.002	L0.002	0.007	L0.001
18-MAR-82	1150	L0.002	0.002	0.006	L0.001
18-MAY-82	1500	L0.002	0.002	0.004	0.001
28-SEP-82	1240	L0.002	L0.002	0.004	L0.001
02-NOV-82	1430	L0.002	L0.002	0.002	L0.001
11-JAN-83	1340	L0.002	L0.002		0.001
15-MAR-83	1445	L0.002	0.003		0.001
11-MAY-83	1325	0.002	0.002		L0.001
19-JUL-83	1040	0.004	L0.002		0.001
13-SEP-83	1020	L0.002	L0.002		L0.001
15-NOV-83	1025	L0.002	L0.002		L0.001
17-JAN-84	1110	L0.002	L0.002		L0.001
16-MAY-84	950	0.003	L0.002		L0.001
24-JUL-84	1030	L0.002	L0.002	L0.01	L0.001
24-JUL-84	1035	L0.002	L0.002	0.010	L0.001
24-JUL-84	1050	L0.002	L0.002	0.010	L0.001
19-SEP-84	1105	0.003	L0.002	0.020	0.005
20-NOV-84	1110	L0.002	L0.002	0.010	L0.001
20-NOV-84	1120	0.002	L0.002	0.010	L0.001
20-NOV-84	1145	L0.002	L0.002	0.010	L0.001
22-JAN-85	1115	L0.002	L0.002	0.010	L0.001
19-MAR-85	1025	L0.002	L0.002	L0.01	L0.001
19-MAR-85	1040	L0.002	L0.002	L0.01	L0.001
19-MAR-85	1050	L0.002	0.002	L0.01	L0.001
09-MAY-85	850	L0.002	L0.002	L.01	L0.001
09-JUL-85	1035	L0.002	0.002	L0.01	0.001
09-JUL-85	1045	L0.002	0.002	L0.01	L0.001
09-JUL-85	1057	L0.002	0.003	0.010	L0.001
26-SEP-85	1510	L0.002	L0.002	L0.01	L0.001
20-NOV-85	1000	L0.002	L0.002	L0.01	L0.001
20-NOV-85	1015	L0.002	L0.002	L0.01	L0.001
20-NOV-85	1030	L0.002	L0.002	L0.01	L0.001

APPENDIX XI : METALS IN BOTTOM SEDIMENTS(MG/KG) - TOMOGONOPS/NW MIRAMICHI AND EXPLOITS RIVER BASINS

	STN	DATE	TIME	TOTAL WATER DEPTH-M	ARSENIC NON-RESID	COPPER NON-RESID	LEAD NON-RESID	ZINC NON-RESID	CADMIUM NON-RESID
1	50NB01BQ0004	21-JUN-84	1100	0.3	110.0	2000	3000	4200	15.0
2	50NB01BQ0004	21-JUN-84	1105	0.3	170.0	3000	3000	2800	8.0
3	50NB01BQ0004	21-JUN-84	1110	0.3	160.0	3000	3000	2300	6.0
4									
5	51NF02YN0020	27-JUL-84	900	20.0	170.0	370	2100	1300	6.3
6	51NF02YN0020	27-JUL-84	905	20.0	170.0	320	1900	1100	10.0
7	51NF02YN0020	27-JUL-84	920	20.0	150.0	230	1800	330	2.3
8	51NF02YN0021	27-JUL-84	1030	37.0	260.0	280	1500	830	5.6
9	51NF02YN0021	27-JUL-84	1035	37.0	180.0	340	2300	750	5.3
10	51NF02YN0021	27-JUL-84	1040	37.0	150.0	310	2300	390	1.4
11	51NF02YN0022	28-JUL-84	1000	32.0	150.0	330	2500	830	4.0
12	51NF02YN0022	28-JUL-84	1030	32.0	150.0	350	2500	600	3.0
13	51NF02YN0022	28-JUL-84	1015	32.0	140.0	310	2500	600	2.6
14	51NF02YN0023	28-JUL-84	1220	41.0	150.0	370	2600	870	4.4
15	51NF02YN0023	28-JUL-84	1225	41.0	170.0	370	2300	1900	9.8
16	51NF02YN0023	28-JUL-84	1230	41.0	140.0	350	2600	900	4.3
17	51NF02YN0024	28-JUL-84	1500	35.0	100.0	300	2400	1200	7.2
18	51NF02YN0024	28-JUL-84	1505	35.0	120.0	330	2500	1100	6.9
19	51NF02YN0024	28-JUL-84	1510	35.0	70.0	300	2300	1200	6.6
20	53NF02YD0002	31-JUL-84	1100	4.0	8.7	38	200	200	2.0
21	53NF02YD0002	31-JUL-84	1115	4.0	10.5	40	200	200	2.0
22	53NF02YD0002	31-JUL-84	1120	4.0	10.7	38	200	200	2.0
23	53NF02YD0003	31-JUL-84	1000	4.0	15.0	65	300	300	2.0
24	53NF02YD0003	31-JUL-84	1005	4.0	14.0	50	300	300	2.0
25	53NF02YD0003	31-JUL-84	1010	4.0	13.0	50	300	300	2.0

	MERCURY TOTAL		%SAND	%SILT	%CLAY	TOC
1	0.210					608000
2	0.140					604000
3	0.220					597000
4						
5	1.000					79000
6	0.700		4.0	68.8	27.2	68000
7	0.950	L1.		77.0	23.0	74000
8	0.930		0.4	74.3	25.3	77000
9	1.000		1.2	73.5	25.3	98000
10	0.820					105000
11	0.239					117000
12	0.910		3.8	71.9	24.3	112000
13	0.580					110000
14	0.550	L1.		71.9	28.1	145000
15	0.820		5.0	75.0	20.0	81000
16	0.480		5.5	72.5	22.0	128000
17	0.510		11.6	66.8	21.6	293000
18	0.370		6.0	70.8	23.2	223000
19	0.390		9.0	67.8	23.2	307000
20	0.670					
21	0.470					
22	0.170					
23	0.450					342000
24	0.190					656000
25	0.130					579000

APPENDIX XII : METALS IN BOTTOM SEDIMENTS(MG/KG) - SALMON/MIRA RIVER BASIN

	STN	DATE	SEDIMENT DEPTH-CM	WATER DEPTH-M	ARSENIC NON-RESID	COPPER NON-RESID	LEAD NON-RESID	ZINC NON-RESID	CADMIUM NON-RESID
1	50NS01FJ0022	05-NOV-85	0-2	0.3	2.02	2.8	68	58	0.50
2	50NS01FJ0022	05-NOV-85	0-2	0.3	1.57	3.1	73	69	0.70
3	50NS01FJ0022	05-NOV-85	0-2	0.3	1.53	3.0	67	61	0.50
4	50NS01FJ0023	05-NOV-85	0-2	0.5	5.65	8.0	2200	800	7.10
5	50NS01FJ0023	05-NOV-85	0-2	0.5	8.10	8.0	2100	800	7.60
6	50NS01FJ0023	05-NOV-85	0-2	0.5	5.53	8.0	2150	800	7.20
7	50NS01FJ0024	05-NOV-85	0-2	0.5	2.91	9.5	2700	700	5.20
8	50NS01FJ0024	05-NOV-85	0-2	0.5	2.84	9.0	2600	700	5.40
9	50NS01FJ0024	05-NOV-85	0-2	0.5	3.21	9.2	2600	700	5.20
10	50NS01FJ0025	05-NOV-85	0-2	0.5	1.68	3.0	120	89	0.92
11	50NS01FJ0025	05-NOV-85	0-2	0.5	2.21	3.0	120	87	0.80
12	50NS01FJ0025	05-NOV-85	0-2	0.5	1.72	3.0	120	89	0.80
13	51NS01FJ0034	05-NOV-85	0-2	5.0	2.03	5.2	470	167	1.90
14	51NS01FJ0034	05-NOV-85	0-2	5.0	2.05	5.6	450	167	1.80
15	51NS01FJ0034	05-NOV-85	0-2	5.0	2.98	5.7	480	170	1.80
16	51NS01FJ0034	05-NOV-85	0-2	5.0					
17	50NS01FJ0001	05-NOV-85	0-2	0.5	1.33	3.6	25	29	0.11
18	50NS01FJ0001	05-NOV-85	0-2	0.5	1.40	3.5	25	30	0.11
19	50NS01FJ0001	05-NOV-85	0-2	0.5	1.75	3.8	25	29	0.13
20	51NS01FJ0027	25-SEP-85	0-2	11.5	7.59	13.0	101	180	2.00
21	51NS01FJ0027	25-SEP-85	0-2	11.5	6.93	14.0	99	170	1.90
22	51NS01FJ0027	25-SEP-85	0-2	11.5	7.96	14.0	98	170	1.80
23	51NS01FJ0027	25-SEP-85	2-5	11.5	2.74	15.0	73	170	1.50
24	51NS01FJ0027	25-SEP-85	5-8	11.5	2.63	15.0	71	170	2.00
25	51NS01FJ0028	25-SEP-85	0-2	21.0	8.26	13.0	119	170	3.00
26	51NS01FJ0028	25-SEP-85	0-2	21.0	7.71	13.0	119	170	1.90
27	51NS01FJ0028	25-SEP-85	0-2	21.0	8.59	13.0	113	180	1.40
28	51NS01FJ0028	25-SEP-85	2-5	21.0	4.63	14.0	101	190	1.50
29	51NS01FJ0028	25-SEP-85	5-8	21.0	4.00	13.0	85	160	1.10
30	51NS01FJ0029	25-SEP-85	0-2	19.5	4.66		108	120	0.70
31	51NS01FJ0029	25-SEP-85	0-2	19.5	4.25	9.7	110	120	1.00
32	51NS01FJ0029	25-SEP-85	0-2	19.5	2.63	9.9	108	110	0.70
33	51NS01FJ0029	25-SEP-85	2-5	19.5	2.07	11.0	101	120	0.90
34	51NS01FJ0029	25-SEP-85	5-8	19.5	1.96	10.0	91	120	0.80
35	51NS01FJ0030	26-SEP-85	0-2	8.5	3.54	10.0	123	190	1.40
36	51NS01FJ0030	26-SEP-85	0-2	8.5	3.47	10.0	125	200	1.40
37	51NS01FJ0030	26-SEP-85	0-2	8.5	6.80	10.0	60	180	0.70
38	51NS01FJ0030	26-SEP-85	2-5	8.5	2.20	10.0	100	210	1.60
39	51NS01FJ0030	26-SEP-85	5-8	8.5	1.83	11.0	90	190	1.60
40	51NS01FJ0031	24-SEP-85	0-2	11.0	3.78	10.0	119	160	0.90
41	51NS01FJ0031	24-SEP-85	0-2	11.0	3.89	10.0	117	160	0.90
42	51NS01FJ0031	24-SEP-85	0-2	11.0	3.94	10.0	117	160	1.00
43	51NS01FJ0031	24-SEP-85	2-5	11.0	2.61	12.0	109	210	1.00
44	51NS01FJ0031	24-SEP-85	5-8	11.0	2.77	9.6	106	200	1.00
45	51NS01FJ0032	26-SEP-85	0-2	7.5	4.38	9.0	116	170	1.60
46	51NS01FJ0032	26-SEP-85	0-2	7.5	2.55	9.0	120	190	1.60
47	51NS01FJ0032	26-SEP-85	0-2	7.5	2.22	10.0	123	190	1.60
48	51NS01FJ0032	26-SEP-85	2-5	7.5	1.48	10.0	100	150	1.10
49	51NS01FJ0032	26-SEP-85	5-8	7.5	1.78	10.0	93	130	0.70
50	51NS01FJ0033	25-SEP-85	0-2	5.0	1.96	9.8	99	190	1.80

APPENDIX XII (CONT) : METALS IN BOTTOM SEDIMENT(MG/KG) - SALMON/MIRA RIVER BASIN

	MERCURY TOTAL	IRON NON-RESID	MANGANESE NON-RESID	ALUMINUM NON-RESID	SAND %	SILT %	CLAY %	TOTAL ORG CARBON
1	L0.02	7200	440	500	62.0	24.0	14.0	
2	0.02	7400	440	500				
3	L0.02	7000	430	500				21000
4	0.02	13000	6000	800	44.2	42.7	13.1	
5	0.09	12000	5300	800				
6	L0.02	12000	5100	800				77000
7	0.07	12000	1900	800	41.0	43.8	15.2	
8	0.08	12000	1800	800				
9	0.10	11000	1900	800				54000
10	0.03	7200	500	500	70.0	22.1	7.9	
11	0.03	6900	500	500				
12	0.03	7200	500	500				60000
13	0.11	9500	600	800				
14	0.11	10000	600	800				
15	0.11	11000	600	800	36.0	49.2	14.8	83000
16					36.0	49.2	14.8	83000
17	0.06	5700	300	400	65.0	22.2	12.8	
18	0.03	6000	280	400				
19	0.02	5900	290	400				25000
20	0.23	34000	8000	8000	10.0	58.8	31.2	60000
21	0.18	34000	7000	8000				66000
22	0.21	33000	7000	8000				63000
23	0.18	27000	4000	9000				65000
24	0.16	33000	4000	10000				71000
25	0.20	31000	17000	8000	5.5	55.0	39.5	70000
26	0.15	28000	16000	8000				64000
27	0.21	30000	16000	9000				64000
28	0.14	25000	6500	10000				64000
29	0.14	29000	6800	9000				67000
30		23000	9700	6000	22.0	47.1	30.9	53000
31	0.14	21000	8700	6000				52000
32	0.16	22000	9000	6000				53000
33	0.16	21000	5000	6000	10.0	59.2	30.8	52000
34	0.13	17000	3400	6000	20.2	58.2	21.6	54000
35	0.18	21000	5000	7000	13.0	53.0	34.0	55000
36	0.16	21000	5000	8000				58000
37	0.14	16000	900	9000				57000
38	0.12	20000	2900	8000	19.4	45.2	35.4	54000
39	0.15	23000	3000	10000	9.0	65.0	26.0	58000
40	0.16	20000	12000	6000	18.0	51.1	30.9	60000
41	0.15	20000	12000	7000				62000
42	0.16	20000	11000	7000				67000
43	0.14	22000	5000	9000	14.2	53.7	32.1	65000
44	0.15	19000	4000	8000				66000
45	0.14	23000	5400	7000	10.0	55.6	34.4	53000
46	0.11	25000	7000	8000				53000
47	0.12	23000	6000	8000				51000
48	0.12	17000	1600	9000	9.0	54.2	36.8	53000
49	0.10	15000	1200	9000	8.0	59.2	32.8	42000
50	0.14	11000	1100	7000	17.6	52.4	30.0	82000

APPENDIX XII (CONT) : METALS IN BOTTOM SEDIMENTS(MG/KG) - SALMON/MIRA RIVER BASIN

	STN	DATE	SEDIMENT DEPTH-CM	WATER DEPTH-M	ARSENIC NON-RESID	COPPER NON-RESID	LEAD NON-RESID	ZINC NON-RESID	CADMIUM NON-RESID
51	51NS01FJ0033	25-SEP-85	0-2	5.0	2.01	9.5	98	160	1.60
52	51NS01FJ0033	25-SEP-85	0-2	5.0	1.93	9.5	101	190	2.00
53	51NS01FJ0033	25-SEP-85	2-5	5.0	2.53	8.0	91	200	2.00
54	51NS01FJ0033	25-SEP-85	5-8	5.0	2.17	8.0	83	190	1.70
55	50NS01FJ0020	26-SEP-85	0-2	2.0	6.55	8.0	57	180	2.00
56	50NS01FJ0020	26-SEP-85	0-2	2.0	6.18	8.0	57	170	1.50
57	50NS01FJ0020	26-SEP-85	0-2	2.0	4.59	7.0	54	180	1.70
58	50NS01FJ0020	26-SEP-85	2-5	2.0	6.99	4.0	56	190	1.90
59	52NS01FJ0002	26-SEP-85	0-2	3.5	19.00	11.0	63	180	0.80
60	52NS01FJ0002	26-SEP-85	0-2	3.5	18.80	11.0	63	180	0.90
61	52NS01FJ0002	26-SEP-85	0-2	3.5	19.10	11.0	64	180	1.90
62	52NS01FJ0002	26-SEP-85	2-5	3.5	9.65	10.0	59	200	0.80
63	52NS01FJ0002	26-SEP-85	5-8	3.5	10.60	7.0	51	200	0.90
64	52NS01FJ0004	24-SEP-85	0-2	6.5	6.53	12.0	29	60	0.60
65	52NS01FJ0004	24-SEP-85	0-2	6.5	6.58	12.0	29	70	0.20
66	52NS01FJ0004	24-SEP-85	0-2	6.5	6.15	12.0	29	60	0.20
67	52NS01FJ0004	24-SEP-85	2-5	6.5	6.93	14.0	31	70	0.20
68	52NS01FJ0004	24-SEP-85	5-8	6.5	6.46	11.0	31	70	0.60

	MERCURY TOTAL	IRON NON-RESID	MANGANESE NON-RESID	ALUMINUM NON-RESID	SAND %	SILT %	CLAY %	TOTAL ORG CARBON
51	0.17	12000	1200	8000				80000
52	0.13	12000	1200	8000				81000
53	0.14	12000	1000	9000	18.0	51.2	30.8	88000
54	0.11	11000	1000	10000	15.7	54.7	29.6	86000
55	0.09	15000	1600	9000				129000
56	0.09	13000	1500	8000				134000
57	0.09	12000	1500	8000				130000
58	0.11	10000	300	9000				165000
59	0.12	22000	1100	10000	16.0	57.2	26.8	101000
60	0.15	19000	970	10000				96000
61	0.13	22000	950	11000				99000
62	0.12	14000	300	10000	24.0	56.4	19.6	105000
63	0.14	14000	200	12000	18.2	58.6	23.2	127000
64	0.08	15000	220	5000	23.7	52.2	24.1	72000
65	0.09	15000	240	5000				71000
66	0.06	14000	220	5000				74000
67	0.05	15000	240	5000	22.5	49.8	27.7	70000
68	0.06	14000	200	5000	27.7	48.2	24.1	72000

APPENDIX XIII : FIELD DESCRIPTIONS - BOTTOM SEDIMENT

2 51NF02YN0020 RED INDIAN LAKE, 1KM E. OF BUCHANS ISLAND

SAMPLES WERE APPROX. 6 CM THICK WITH A BROWNISH DUSTING OF CLAY ON SURFACE AND A GOLDEN-BROWN LAYER OF LIGHT TO MEDIUM DENSITY CLAY BELOW PROGRESSING TO A GREENISH-GREY LAYER ON THE BOTTOM. SOME STONES AND SAND ON LOWER LEVEL. ALL SAMPLES SIMILAR.

3 51NF02YN0021 RED INDIAN LAKE, APPROX. 3.2KM BELOW BUCHANS BROOK NEAR CENTER.

SAMPLES SIMILAR TO (1) BUT MORE PLENTIFUL. 7.5 CM APPEARED TO BE FORMED IN SHEETS WITH A LIGHT BROWN LIGHT DENSITY CLAY ABOUT 1 CM., THEN TO GOLDEN BROWN A MYRIAD OF COLORS IMMEDIATELY BELOW AND GREENISH-GREY TO BLACK MEDIUM DENSITY CLAY ON BOTTOM.

4 51NF02YN0022 RED INDIAN LAKE, 5KM WNW OF EXPLOITS RIVER DAM.

10 CM. SAMPLES DIFFERED FROM (1) AND (2) SINCE THEY HAD AN OBVIOUS LIGHT DENSITY MED-BROWN SURFACE LAYER APPROX. 1 CM. THICK. SIX DISTINCT LAYERS WERE VISIBLE. FOR THE MOST PART, THE LAYERS WOULD SEPARATE IN THE TRAY BY THEMSELVES (AS UNITS). FROM THE SURFACE THE LAYERS MAY BE DESCRIBED AS FOLLOWS:

(A) MED-BROWN, LIGHT DENSITY -) 1 CM
(B) LIGHT TO GOLDEN BROWN, LIGHT TO MED DENSITY -) 1 CM
(C) MYRIAD OF BROWNS, MED-DENSITY - 1 CM
(D) MED-BROWN, MED-DENSITY -) 0.5 CM
(E) MED BROWN, MED-DENSITY -) 1 CM
(F) BLACK, MED TO VERY DENSITY - REMAINDER

5 51NF02YN0023 RED INDIAN LAKE, APPROXIMATELY 1.8 KM FROM EXPLOITS RIVER DAM.

SAMPLES VERY SIMILAR TO (3) HOWEVER ONLY 4 THICKER LAYERS WERE OBVIOUS AND READILY SEPARATED ON THEIR OWN. ALL SAMPLES WERE SIMILAR. ABOUT 1.5 CM USED FOR SAMPLE.

6 51NF02YN0024 RED INDIAN LAKE, 4 KM W. OF MILLERTOWN AT CENTER

FEWER LAYERS EVIDENT AT THIS SITE. A THIN MED-BROWN SURFACE CLAY WAS PRESENT WITH DECAYED SAWDUST AND WOOD CHIPS EVIDENT IN THE NEXT LOWER LAYER. THE BLACK REDUCED LAYER WAS THICKER, PERHAPS HALF THE SAMPLE DEPTH. SAMPLES WERE SIMILAR, WITH 1.5 CM USED FOR SAMPLE.

13 52NF02YD0012 BAY OF EXPLOITS, 1.3 KM SW OF HIGH POINT AT CENTER

10 TO 12 CM SAMPLES WITH) 1 CM OF MED-BROWN ORGANIC-CLAY MATERIAL ON SURFACE WITH REMAINDER OF SAMPLE BLACK REDUCED MEDIUM DENSITY MATERIAL. VERY STRONG ORGANO-SULFUR ODOR, RESULTING FROM PULP, FIBRE WHICH MADE UP THE MAJORITY OF SAMPLE. ALL SAMPLES SIMILAR WITH 1.5 CM USED FOR SAMPLE.

14 52NF02YD0013 BAY OF EXPLOITS, APPROX. HALF WAY BETWEEN LITTLE PETER AND WIGWAM POINTS

SEDIMENT SIMILAR TO (6) HOWEVER NO SURFACE OXIDIZED MATERIAL PRESENT. PULP FIBRE WAS HOMOGENOUS IN SAMPLE, BLACK IN COLOR (ALMOST TAR-LIKE) WITH VERY STRONG ORGANIC-SULFIDE ODOR. SAMPLE WAS MORE WATERY IN CONSISTENCY THAN (6) MAKING IT DIFFICULT TO SUB-SAMPLE THE SURFACE LAYER. APPROX. 1.5 CM USED FOR SAMPLE.

APPENDIX XIV : METAL IN FISH (MG/KG-WET WEIGHT) - NW MIRAMICHI,EXPLOITS AND MIRA RIVER BASINS

BASIN SPECIES	SAMPLE IDENT	ARSENIC	COPPER	LEAD	ZINC	CADMIUM	MERCURY	ALUMINUM	IRON	LIPID
NW MIRAMICHI										
LAKE CHUB	1	0.071	1.30	0.06	79.0	0.084	0.100	-	-	2.19
		0.059	1.20	0.06	86.0	0.068	0.080	-	-	3.26
		0.060	1.50	0.07	78.0	0.089	0.070	-	-	2.26
EXPLOITS										
LAND-LOCK SALMON	1	L0.001	0.45	0.07	8.0	L0.02	0.620	-	-	2.64
	2	L0.001	0.42	0.15	6.0	0.020	0.310	-	-	2.44
	3	L0.001	0.36	0.15	9.0	0.030	0.460	-	-	1.57
	4	L0.001	0.32	0.09	12.0	0.050	0.550	-	-	1.99
	5	L0.001	0.47	0.08	9.0	0.000	0.310	-	-	2.16
	6	L0.001	0.43	0.15	9.6	0.040	0.240	-	-	1.45
MIRA										
LONGNOSE SUCKER	1	L0.001	1.20	0.09	4.2	L0.01	0.105	7.3	9.9	-
		L0.001	1.20	0.08	4.2	L0.01	0.095	8.1	8.6	-
		-	1.20	0.11	4.2	L0.01	0.098	8.2	8.3	-
		-	1.20	0.14	4.1	L0.01	-	7.4	8.3	-
	2	L0.001	0.78	0.09	4.1	L0.01	0.180	2.9	5.9	-
		L0.001	0.78	0.08	4.1	L0.01	0.200	3.2	5.7	-
		-	0.73	0.08	3.8	L0.01	0.220	2.7	5.5	-
		-	0.74	0.08	3.9	L0.01	-	2.7	5.8	-
	3	L0.001	0.81	0.08	3.6	L0.01	0.108	4.9	7.2	-
		L0.001	0.82	0.08	3.6	L0.01	0.102	5.2	7.0	-
		-	0.84	0.08	3.7	L0.01	0.096	5.8	7.1	-
		-	0.82	0.05	3.6	L0.01	-	5.4	7.0	-
	4	L0.001	1.80	0.09	3.7	L0.01	0.095	4.6	4.4	-
		L0.001	1.80	0.10	3.9	L0.01	0.094	5.4	5.7	-
		-	1.90	0.12	3.8	L0.01	0.101	5.2	4.5	-
		-	2.00	0.19	3.9	L0.01	-	4.9	4.5	-
	5	L0.001	0.74	0.13	4.7	L0.01	0.029	9.0	10.4	-
		L0.001	0.78	0.13	4.8	L0.01	0.039	9.1	9.9	-
		-	0.80	0.14	4.6	L0.01	-	9.8	9.7	-
		-	0.84	0.11	4.7	L0.01	-	10.0	10.6	-
	6	L0.001	0.59	-	5.2	L0.01	0.043	11.1	13.4	-
		L0.001	0.56	0.12	5.1	L0.01	0.036	12.3	14.2	-
		-	0.59	0.16	5.0	L0.01	0.056	9.4	17.3	-
		-	0.55	0.15	5.2	L0.01	-	9.0	14.0	-
WHITE PERCH	7	L0.001	0.84	0.18	6.2	L0.01	0.520	22.0	20.2	-
		L0.001	0.74	0.22	5.7	L0.01	0.440	15.6	15.1	-
		-	0.83	0.22	6.0	L0.01	0.540	16.4	16.6	-
		-	0.84	0.18	5.7	L0.01	-	16.0	17.7	-
	8	L0.001	1.70	0.14	6.2	0.080	0.540	5.9	5.3	-
		L0.001	1.60	0.15	6.8	0.080	0.540	5.9	6.2	-
		-	1.70	0.15	6.3	0.090	0.520	5.2	5.5	-
		-	1.70	0.11	6.0	0.090	0.540	5.4	5.4	-

APPENDIX XV : PHYSICAL DESCRIPTION OF FISH (SAMPLES)

BASIN SAMPLE IDENT	SPECIES	GROUPING	LENGTH/RANGE CM	TOTAL WEIGHT KG
NW MIRAMICHI	LAKE CHUB	30+	0.8-2.0	-
EXPLOITS				
1	L-L SALMON	1	39.0	0.62
2	L-L SALMON	1	34.0	0.39
3	L-L SALMON	1	40.0	0.48
4	L-L SALMON	1	39.0	0.46
5	L-L SALMON	1	37.0	0.41
6	L-L SALMON	1	37.0	0.39
MIRA				
1	LONGNOSE SUCKER	1	45.5	2.10
2	LONGNOSE SUCKER	1	47.0	2.20
3	LONGNOSE SUCKER	1	42.5	1.60
4	LONGNOSE SUCKER	1	39.0	1.20
5	LONGNOSE SUCKER	5	23.0-26.0	0.55
6	LONGNOSE SUCKER	5	25.0-30.0	1.10
7	WHITE PERCH	8	18.0	0.56
8	WHITE PERCH	3	17.0-21.0	0.26